(12)

ORNL-6230

DTIC FILE COPY

ornl

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

AD-A183 916

Studies of Postdisaster Economic Recovery: Analysis, Synthesis, and Assessment

Lawrence J. Hill

DTIC
S ELECTE D
AUG 1 8 1987
D

Interagency Agreement DOE 40-1457-84
and FEMA EMW-84-E-1737, Work Unit 3521 C

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

87 8 14 066

Energy Division

STUDIES OF POSTDISASTER ECONOMIC RECOVERY: ANALYSIS, SYNTHESIS, AND ASSESSMENT

Lawrence J. Hill

Energy and Economic Analysis Section

Date Published: June 1987

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

Prepared for the
FEDERAL EMERGENCY MANAGEMENT AGENCY
Washington, D.C. 20472
Interagency Agreement; FEMA No. EMW-84-E-1737
(Work Unit No. 3521 C) and DOE No. 40-1457-84

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER ORNL-6230	2. GOVT ACCESSION NO. AD-A183916
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) STUDIES OF POSTDISASTER ECONOMIC RECOVERY: ANALYSIS, SYNTHESIS, AND ASSESSMENT	5. TYPE OF REPORT & PERIOD COVERED FINAL REPORT
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) LAWRENCE J. HILL	8. CONTRACT OR GRANT NUMBER(s) FEMA EMW-84-E-1737
9. PERFORMING ORGANIZATION NAME AND ADDRESS OAK RIDGE NATIONAL LABORATORY P.O. BOX X OAK RIDGE, TN 37831-6205	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS WORK UNIT #3521C
11. CONTROLLING OFFICE NAME AND ADDRESS FEDERAL EMERGENCY MANAGEMENT AGENCY WASHINGTON, DC 20472	12. REPORT DATE MAY 1987
	13. NUMBER OF PAGES 302
14. MONITORING AGENCY NAME & ADDRESS (If different from Controlling Office)	15. SECURITY CLASS. (of this report)
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE UNCLASSIFIED

16. DISTRIBUTION STATEMENT (of this Report)

N/A

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

ECONOMIC RECOVERY
POSTDISASTER RECOVERY
MODELS OF ECONOMIC RECOVERY
POSTDISASTER MANAGEMENT
POSTDISASTER REORGANIZATION
NATURAL AND TECHNOLOGICAL HAZARDS
POLICY OPTIONS

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

SEE ATTACHED

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT

The purpose of this report is to analyze, synthesize, and assess the extant literature on postdisaster economic recovery in the context of providing a background for policy development. For purposes of the study, the U.S. economy has been divided into two broad components--the physical infrastructure and the institutional infrastructure. The former is comprised of factors of production or, alternatively, all tangible resources used in production, while the latter encompasses the environment that facilitates and coordinates economic exchange.

Three broad approaches have been used to address issues associated with the physical infrastructure in the aftermath of a disaster. They include (1) economic resource assessments; (2) the use of formal economic models to simulate the performance of a postdisaster economy; and (3) individual industry studies. Based on an analysis of the contributions to the literature on the physical infrastructure, three conclusions were drawn. First, the magnitude of potential destruction of economic resources under hypothetical disaster scenarios has been documented. Second, problems that could potentially thwart economic recovery have been detailed. Third, the economic conditions--in a conceptual sense--under which recovery is likely to occur have been formulated.

Research on the institutional infrastructure has been assessed in the context of the reconstruction of the German economy following World War II. The primary recommendation is that further analysis should be undertaken to develop an organization and stabilization program that is consistent with fiscal and monetary reform and damage compensation. The program should place less emphasis on central administration and price controls than some observers have argued.

Accesion For
NTIS CRA&I ☒
DTIC TAB ☐
Unannounced ☐
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A-1

DTIC COPY INSPECTED 6

CONTENTS

LIST OF FIGURES vii

LIST OF TABLES vii

ABSTRACT ix

SUMMARY S-1

1. INTRODUCTION 1-1

2. OVERVIEW OF STUDIES OF THE PHYSICAL INFRASTRUCTURE 2-1

2.1. Introduction 2-1
2.2. Studies of the National Economy 2-2
2.3. Studies of Regional/Local Economies 2-10
2.4. Individual Industry Studies 2-13

3. PHYSICAL INFRASTRUCTURE: STUDIES OF THE NATIONAL ECONOMY 3-1

3.1. Studies Using Economic Models 3-1
3.1.1. The Rand Corporation 3-1
3.1.2. Engineering Strategic Studies Group 3-7
3.1.3. Institute for Defense Analyses 3-8
3.1.4. Stanford Research Institute 3-25
3.1.5. Arms Control and Disarmament Agency 3-28
3.1.6. Research Analysis Corporation 3-30
3.1.7. American Technical Assistance Corporation 3-33
3.1.8. Federal Preparedness Agency 3-36
3.1.9. Analytical Assessments Corporation 3-39
3.1.10. Pugh-Roberts Associates 3-41
3.1.11. Decision Sciences Applications 3-45
3.1.12. Battelle Pacific Northwest Laboratories 3-46
3.2. Studies Using Nonmodeling Methods 3-51

4. PHYSICAL INFRASTRUCTURE: STUDIES OF REGIONAL/LOCAL ECONOMIES . . 4-1

4.1. Studies Using Economic Models 4-1
4.2. Studies Using Nonmodeling Methods 4-10

5. PHYSICAL INFRASTRUCTURE: INDIVIDUAL INDUSTRY STUDIES 5-1

5.1. Introduction 5-1
5.2. The Aluminum Industry 5-4
5.3. The Chemical Industry 5-6
5.4. The Construction Industry 5-6
5.5. The Drug/Antibiotic Industry 5-7
5.6. The Electric Power Industry 5-8
5.7. The Natural Gas Industry 5-12
5.8. The Petroleum Industry 5-15
5.9. The Process Control Industry 5-20
5.10. The Rubber Industry 5-21

CONTENTS (CONTINUED)

5.11. The Steel Industry 5-22
5.12. The Transportation Industries 5-23

6. INSTITUTIONAL INFRASTRUCTURE 6-1

6.1. Introduction and Summary 6-1
6.2. Economic Organization and Stabilization 6-5
6.3. The Monetary System 6-23
6.4. The Fiscal System 6-26
6.5. Damage Compensation 6-28
6.6. Historical Analogue:
Germany in the Aftermath of World War II. 6-36

7. ASSESSMENT OF RESEARCH ON POSTDISASTER ECONOMIC RECOVERY 7-1

7.1. Introduction 7-1
7.2. An Overview of Postdisaster Research in the Context of the
U.S. Economic System 7-3
7.3. Physical Infrastructure 7-7
7.4. Institutional Infrastructure 7-13

8. CONCLUSION 8-1

BIBLIOGRAPHY B-1

LIST OF FIGURES

Number	Title	Page
3.1	Conditions for Economic Recovery	3-6
3.2	The IDA Postattack Economic Model	3-16
3.3	The General Equilibrium Model of the MEVUNS System	3-21
3.4	General Scheme of a Survival Requirements Model	3-31
3.5	Postattack Model Number 4	3-40
3.6	Soft-Minimum Production Function	3-42
3.7	Simulated Real GNP under Three Attack Scenarios, Economic Recovery Dynamics Model	3-47
3.8	Simulated Real GNP under Alternate Assumptions of Psychological Effects, Economic Recovery Dynamics Model	3-49
3.9	Simulated Real GNP under Two Monetary Policy Scenarios, Economic Recovery Dynamics Model	3-50
4.1	A Regional Multicomponent Manufacturing Model	4-3
4.2	A Resource Systems Regional Model	4-6
7.1	Schematic Representation of the U.S. Economic System	7-4

LIST OF TABLES

Number	Title	Page
2.1	Studies of the National Economy, Economic Models	2-4
2.2	Summary of Modeling Studies of the Postattack National Economy	2-5
2.3	Studies of the National Economy, Nonmodeling Methods	2-9
2.4	Studies of Regional/Local Economies, Economic Models	2-10
2.5	Studies of Regional/Local Economies, Nonmodeling Methods	2-12
2.6	Individual Industry Studies	2-14

ABSTRACT

STUDIES OF POSTDISASTER ECONOMIC RECOVERY: ANALYSIS, SYNTHESIS, AND ASSESSMENT

Lawrence J. Hill

The purpose of this report is to analyze, synthesize, and assess the extant literature on postdisaster economic recovery in the context of providing a background for policy development. For purposes of the study, the U.S. economy has been divided into two broad components--the physical infrastructure and the institutional infrastructure. The former is comprised of factors of production or, alternatively, all tangible resources used in production, while the latter encompasses the environment that facilitates and coordinates economic exchange.

Three broad approaches have been used to address issues associated with the physical infrastructure in the aftermath of a disaster. They include (1) economic resource assessments; (2) the use of formal economic models to simulate the performance of a postdisaster economy; and (3) individual industry studies. Based on an analysis of the contributions to the literature on the physical infrastructure, three conclusions were drawn. First, the magnitude of potential destruction of economic resources under hypothetical disaster scenarios has been documented. Second, problems that could potentially thwart economic recovery have been detailed. Third, the economic conditions--in a conceptual sense--under which recovery is likely to occur have been formulated.

Research on the institutional infrastructure has been assessed in the context of the reconstruction of the German economy following World War II. The primary recommendation is that further analysis should be undertaken to develop an organization and stabilization program that is consistent with fiscal and monetary reform and damage compensation. The program should place less emphasis on central administration and price controls than some observers have argued.

Three other areas have been identified which, if addressed, could significantly improve planning for economic recovery. First, attention must be devoted to developing economic control measures in the event that the economy becomes increasingly fragmented over a period of time due to a prolonged nuclear conflict. Second, in an extension of research undertaken over the past three decades, the transportation industries and the production and use of electronic control devices should be the subjects of further study. Finally, most studies of economic recovery have dealt with the U.S. domestic economy, excluding important international considerations. Therefore, attention should be devoted to problems with both the international monetary system and international trade in the aftermath of a generalized disaster. The latter problem is especially important because of the likelihood that many economies throughout the world will not be directly affected by the disaster.

SUMMARY

STUDIES OF POSTDISASTER ECONOMIC RECOVERY: ANALYSIS, SYNTHESIS, AND ASSESSMENT

Lawrence J. Hill

INTRODUCTION

The purpose of this study is to analyze, synthesize, and assess the extant literature on postdisaster economic recovery in the context of providing a background for policy development. The magnitude of disasters under consideration is all-inclusive. Therefore, economic recovery from relatively localized disasters that are the result of natural phenomena--earthquakes, floods, and tornadoes, for example--is considered as well as economic recovery from a generalized disaster resulting from a hypothetical nuclear attack.

It must be emphasized at the outset that, with respect to a hypothetical generalized disaster, only studies associated with some aspect of <u>economic</u> recovery from the disaster are considered in the study. Therefore, research undertaken on strategic and military considerations, continuity of government issues, and biological and meteorological effects of the disaster is beyond the scope of this study. The extent to which these factors could impinge on economic recovery--and the problems that could arise because of them--may be fruitful topics of other research endeavors.

For purposes of this study, the U.S. economy has been divided into two broad components--the physical infrastructure and the institutional infrastructure. The physical infrastructure is comprised of factors of production or, alternatively, all tangible resources used in the process of producing goods and services. It includes land, labor, capital, energy, and other inputs in the production process. The institutional infrastructure, on the other hand, encompasses the environment in which productive economic activity occurs. It can be viewed as the established social, political, and economic arrangements that facilitate and coordinate economic exchange. Economic institutional issues include organization and stabilization of the economy in concert with other monetary, fiscal, legal, and social arrangements that provide the environment for productive activity.

The report is divided into eight chapters. Besides an introduction and a concluding chapter, there are six substantive chapters. Chapters 2 through 5 and Chapter 6 present research results on the physical and institutional infrastructures, respectively. Chapter 7 provides an assessment of the research presented in the preceding five chapters.

Both the discussion of the physical and institutional infrastructures are organized in a hierarchical manner. That is, they are introduced with a summary of the methodologies and results at the beginning

of the discussion. For the physical infrastructure, Chapter 2 provides the summary. The beginning of Chapter 6 contains the summary of research on the institutional infrastructure. The remainder of the discussion on the two broad components of the economy provides a more in-depth analysis of prior research in the respective areas, highlighting the contributions of individual studies. The synopsis of prior research on the two components of the economy is intended to provide the interested reader with a broad overview of research approaches, scope, and results that comprise the extant literature on postdisaster economic recovery.

The organization used to present prior research on the physical infrastructure in Chapters 2 through 5 was dictated by both the methodology and geographical scope of prior research. That is, besides the summary of research in Chapter 2 alluded to above, the discussion of physical infrastructural issues is organized on the basis of (a) studies of the national economy in Chapter 3--further divided between studies using formal economic modeling approaches and nonmodeling methods, (b) studies of regional or local economies in Chapter 4--again divided between studies using modeling approaches and nonmodeling methods, and (c) individual industry studies in Chapter 5, which include industry studies of aluminum, rubber, steel, chemicals, drugs, construction, transportation (surface modes, rail, water, and air), petroleum (including pipelines), natural gas, and electric power.* No distinction is made in the classification between studies of economic recovery from geographically localized or generalized disasters. However, the distinction is obvious from the content of the research.

The presentation in Chapter 6 on the institutional infrastructure is organized around four critical issues in a postdisaster economy: (1) economic organization and stabilization, (2) the monetary system, (3) the fiscal system, and (4) damage compensation. Here again, no distinction is made in the discussion on the type of disaster under consideration. However, the majority of research on institutional issues associated with natural disasters has been concentrated on damage compensation or, more specifically, a comprehensive program of disaster insurance. The presentation in Chapter 6 concludes with a discussion of a historical analogue--the economic reconstruction of post-World War II Germany--which is used to isolate issues that are important for recovery of a severely damaged economy. Although it is recognized that there is no perfect historical analogue for the likely extent of damage and disruption in the aftermath of nuclear attack, the discussion is at the very least suggestive of the economic problems that might arise as a direct result of policies adopted in reconstructing a seriously damaged economy.

---

*A postattack economy can be characterized in stages--defined somewhat arbitrarily on a temporal basis--which reflect priorities in the recovery effort: a population maintenance phase, a reorganization phase, and a recovery phase. Emphasis in this study is placed on the reorganization and recovery phases. Therefore, the food production and processing industries which are instrumental in the population maintenance phase are excluded from this study. However, they are included in other ongoing work on postattack recovery.

To provide a framework for discussion of prior research undertaken on postdisaster economic recovery, Figure S.1 contains a somewhat simplified characterization of the U.S. economic system. The framework provided in Figure S.1 emphasizes the relationship of various components of the total economic system to one another and, as such, does not attempt to characterize the flow of goods or money through individual sectors of the economy. The framework is presented as a convenient means to systematically show the nature and extent of research that has been undertaken on various aspects of a postdisaster economy.

The uppermost echelon of the figure--population, resources, and institutions--provides a highly aggregated representation of the sources of inputs into the economic system. Disaggregating, population and resources can be viewed as comprising the inputs into the production process or, technically, factors of production. Those factors have a number of dimensions which include their quantity, quality, composition, and geographical dispersion. Institutions that have evolved to coordinate or provide an environment for productive activity can be generalized into those related to social, political, and economic aspects of the nation. Factors of production used by industry, final demand for goods, and economic institutions shown in the third and fourth echelons of Figure S.1 provide the framework around which the research reviewed in Chapters 2 through 5 and Chapter 6 was organized--namely, the physical and institutional infrastructures, respectively. When aggregated, final demand components in the fourth echelon--net of imports--constitute the gross national product of the economy.

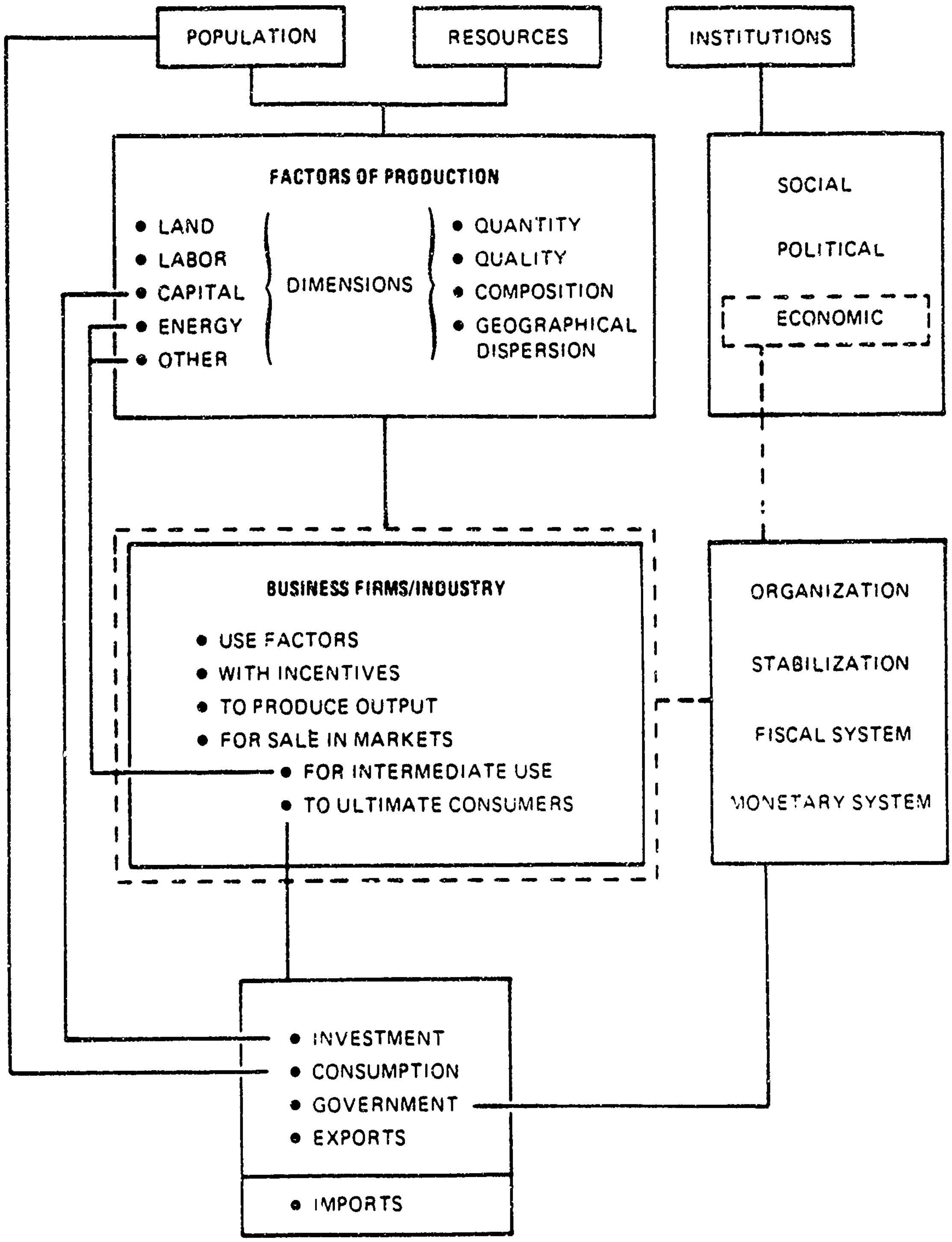
To varying degrees, studies of the postdisaster economy have addressed every component of the economic system depicted in Figure S.1. Highly aggregated studies of the national economy have assessed the vulnerability of the three components of national resources as reflected in the first echelon of Figure S.1--population, resources, and institutions. In these studies, economic resources typically have been measured as manufacturing value added and institutions have been measured in terms of private and public decisionmakers (corporate management and government administrators).

Although, very little analytical research has been undertaken on the institutional infrastructure relative to research on issues associated with the physical infrastructure, all of the economic institutional issues presented in Figure S.1 have been addressed. Questions of optimal organization of the postattack economy and stabilization measures have received the most attention. For the most part, potential problems with fiscal and monetary reform have been discussed in a speculative manner.

A number of studies have addressed surviving factors of production under alternate attack scenarios. These studies have addressed various dimensions of those factors as presented in Figure S.1, with inferences drawn about the ability of the surviving population, labor force, and management to harness them into a viable economy.

The majority of studies of postattack economic recovery have addressed issues associated with the ability of estimated surviving indus-

Figure S.1
Schematic Representation of the U.S. Economic System



trial capacity to both generate output sufficient to sustain the surviving population and grow sufficiently to attain a reasonable per-capita standard of living. In terms of Figure S.1, these studies addressed business firms/industries and final demands. The studies have been conducted at both the national and subnational levels. Methodologies employed have included formal modeling approaches, nonmodeling resource assessments, and studies of individual industries.

The remainder of this summary contains three sections. The following two sections provide an overview and assessment of research on the physical and institutional infrastructures. The final section presents conclusions and four recommendations for future research.

PHYSICAL INFRASTRUCTURE

Analysis of the economic effects of relatively localized disasters as would result from natural phenomena has generally proceeded along two fronts. First, in the majority of studies, prior disasters have been analyzed using historical time series data to ascertain both the short- and long-term effects of the disaster on the regional economy. Typically, aggregate economic indicators--employment and retail sales, for example--have been analyzed (1) for a period of time prior to the disaster, (2) during the period immediately following a disaster, and (3) for the long term, over a number of years to determine if the disaster had any perceptible influence on the economy as reflected in economic indicators. Second, economic models have been used either to simulate the performance of the economy during the disaster period to determine the effects of the disaster or to simulate the effects of a hypothetical disaster.

In general, the results of studies of geographically localized disasters have shown that there are no long-term effects of natural disasters on regional economies. For the short term, the studies have generally shown that the disaster provides a stimulus to the local economy.* In an econometric simulation study of the long-term economic impact of a hypothetical earthquake in the Charleston, South Carolina metropolitan area, for example, Ellson, Milliman, and Roberts' (1984) conclusion is typical of the conclusions of studies of the long-term effects of natural disasters:

> What is clear is that the health of the regional economy is determined more by the assumptions one makes about the national (exogenous) growth factors driving the regional economy than by the disruptive effects of an earthquake whose severe

---

*The only prominent exception to these general statements on short- and long-term recovery from geographically localized disasters is a potentially devastating earthquake in California. For simulations of the performance of the regional economy in the aftermath of a hypothetical earthquake in California, see Cochrane (1975) and Munroe and Ballard (1983).

> effects are largely temporary and tend to diminish over the longer run. (Ellson, Milliman, and Roberts, 1984, p. 570).

Moreover, in an analysis of statistical time series data to determine the economic effects of the 1964 earthquake in Alaska, one of Dacy and Kunreuther's (1969) conclusions reflects the general results obtained from analyses using aggregate economic indicators to ascertain the effects of natural disasters:

> In fact, a disaster may turn out to be a blessing in disguise. Aside from the economic boom that often follows because of the large amount of reconstruction, there is an opportunity for commercial establishments and homeowners to improve their facilities. (Dacy and Kunreuther, 1969, p. 168).

The literature on the physical infrastructure of the economy in the aftermath of a large-scale nuclear disaster can be viewed in the aggregate as attempting to answer two broad questions:

1. Do resources survive in sufficient quantities to accommodate economic recovery on a national or regional basis after a hypothetical disaster?

2. What are the physical impediments to economic recovery?

Three broad approaches have been used to address these questions: (1) assessment of surviving economic resources; (2) simulation of economic models; and (3) studies of individual industries.

National or subnational economic resource assessments have ranged from simple analyses of surviving population, labor, and industrial capacity in the aftermath of hypothesized nuclear attacks to relatively detailed analyses of the surviving labor-capital composition. In general, the results of the studies showed that prospects for economic recovery from the hypothetical attacks were favorable. Hanunian (1966), for example, postulated eight hypothetical attacks that were intended to span the range of plausible attack scenarios at the time of writing. He concluded that recovery prospects are favorable with farm output outperforming nonfarm output in the immediate postattack period. Although Addington's (1968) analysis of the results of several hypothetical attack scenarios showed that there would be a labor-capital imbalance in the postattack economy, he concluded that the prospects for recovery are favorable because labor could be applied to capital more intensively in the postattack economy.

Goen et al. (1967, 1969) examined various facets of economic recovery under two attack scenarios--a counterforce strike (directed primarily at military facilities) and a countervalue strike (directed primarily at economic and population centers). Aspects of the postattack economy under examination were population, manufacturing capacity, industrial and public management, agriculture/food processing, homeless survivors, and the availability of labor for manufacturing activities. Although under both attack scenarios the authors concluded that the output required for producing intermediate goods did not exceed available ca-

pacity, the demand for food products would exceed undamaged capacity by 40 percent under the countervalue scenario. Under both attack scenarios, petroleum refining capacity would be more than adequate to service postattack demands. However, in a study of the number of additional weapons required to reduce petroleum capacity below the level required for recovery, the authors concluded that seven additional weapons would produce a bottleneck in the petroleum sector. Other sectors especially vulnerable to imbalancing attacks were printing and publishing (one additional weapon) and instruments (three). Additionally, after examining the surviving labor force and manufacturing capacity, the authors concluded that imbalances in the supply of labor would reduce manufacturing output by approximately 20 percent of what it could be with surviving physical resources.

Laurino and Dresch (1971) examined the Soviet threat of the 1970s, the constraints placed on that threat, the ability of the United States to take counteraction, and prospects for economic recovery. Defining four levels of economic viability--adequate, imbalanced, austere, and moribund--the authors concluded that, under the constraints placed on the Soviets in the early and mid-1970s, they could reduce the United States to the imbalanced level of viability. Reduction to the austere level would require changes in Soviet objectives. An imbalanced level means that the economic system cannot function at the required level even though surviving capacity is adequate in most sectors. The austere level means that economic capacity can only sustain the surviving population.

The results of the more general resource assessments--percentage of preattack population, labor force, and industrial capacity surviving an attack, for example--were used to draw inferences about the capability of the region under examination to recover from a hypothetical attack. Since they do not generally provide any indication of the ability of surviving management to harness these resources into a viable mechanism for recovery, the results can at best be used to identify potential problems with surviving physical resources in the postattack economy and do not provide a definitive statement on recovery potential.

With respect to the use of economic models to simulate the performance of the postattack economy under hypothetical attack scenarios, an approach that lends itself well to isolating problems of potential significance in economic recovery is input-output modeling. Input-output models cast in a linear programming framework have been used extensively to address problems related to imbalances or bottlenecks in a damaged economy. Bottlenecks can be identified that impede the production of both intermediate and final goods in the postattack economy.

The level of aggregation across individual industries in input-output studies has been dictated by available data on the inter-industry production coefficients in the economy. The earliest studies of the postattack recovery potential of the U.S. economy were highly aggregated across individual industrial sectors of the economy. For example, Clark's 1958 study of the recovery potential of the economy was based on nine highly aggregated sectors [see Kahn et al. (1958)]. Ensuing

studies using the input-output approach were disaggregated in accordance with data on inter-industry production coefficients.

While nearly all of the studies using an input-output approach found limiting factors in recovery--bottlenecks, for example--the potential for economic recovery was found to be generally favorable in the earlier studies. For example, after analyzing two hypothesized attacks in 1975, Bickley, Crane, and Pearsall (1967) concluded that the surviving population would enjoy a standard of living comparable to the late 1950s. One of the attacks they considered was a large-scale countervalue strike in which it was estimated that 90 million people and 34 to 41 percent of the capital stock would be destroyed. Bull (1973a, 1973b) simulated the economic performance of the economy in the first 90 days after a hypothetical attack. Under the attack scenario, only 55.7 percent of the population and 34.4 percent of industrial capacity were estimated to survive. Bull's conclusion was that the damaged economy could produce essentials for survival in the 90-day period.

Sobin (1968b, 1969) simulated the number of people who could be supported by surviving economic resources after a large-scale, countervalue attack on the United States. His primary conclusion was that a relatively small amount of investment in key sectors of the economy ($295 million at the time) would lead to economic output that could potentially support an additional 49 million survivors, increasing the total supported population from the original 151 million to 200 million. Dresch and Baum (1973) simulated the performance of the economy under a wide range of attack scenarios and under different assumptions about the amount of postattack investment expenditures made in selected sectors of the economy. The results of their analysis suggested that recovery prospects are favorable and, after the heavier of the simulated attacks, recovery to preattack levels of GNP could occur within a decade. Pearsall (1968) simulated the performance of the economy to ascertain whether it could attain a 1958 standard of living. Numerous hypothetical attacks to create bottlenecks in individual sectors of the economy were designed for the study. Although Pearsall concluded that attacks concentrated on individual economic sectors could be devised to thwart recovery, he believed that the destruction of economic resources resulting from the attacks could be overcome by resorting to alternative sources of supply, substitutions, labor intensive operations, and appropriately applied investment expenditures.

Although the results of simulation studies using an input-output approach have generally shown that the potential for economic recovery is favorable, the input-output approach has a number of limitations that are especially important in the context of simulating postattack recovery potential. First, the input-output coefficients reflect peacetime production relationships. Their use for simulation of the postattack economy does not consider potentially severe disruptions in economic relationships. Second, economic activity within any individual aggregated sector in the models is assumed to be homogeneous. That is, all products and processes are assumed the same. Third, and related to the second assumption, all activity within an individual sector is assumed completely substitutable within that sector and, in contrast, no potential substitution of products or processes across different sectors

is embodied in the specification of the models. Finally, at least for national models of the postattack economy, the production relationships are aggregated geographically which masks many of the important interregional problems that may arise in the postattack economy. The most prominent of these potential problems involve transportation across regions of the country.

Many potential problems in the postattack economy that are masked by input-output studies have surfaced in studies of individual industries. In a recent study of the aluminum industry, for example, Block et al. (1977) examined, among other issues, the relevance of a relatively disaggregated 367-sector input-output representation of the U.S. economy for analysis of postattack problems in the aluminum industry. With respect to input-output tables, the authors concluded:

> A review of a highly disaggregated set of economic input/output coefficients (367 sectors) indicated input sectors with low dollar values but without suitable substitutes. Therefore, performing a postattack sensitivity analysis to determine the relative importance of ingredients for rebuilding based upon input/output coefficients (in other words, relative price) is meaningless. In addition, capital equipment is included only at a gross level of aggregation and at typical annual depreciation levels--not at plant replacement levels. Furthermore, some supplies necessary to normal operations (such as refractory brick) are not included in the tables. (Block et al., 1977, p. 24).

A number of other in-depth studies of individual industries illuminated potential problems problems in economic recovery that cannot be captured in input-output studies. The work of McFadden and Bigelow (1966)--the steel and petroleum refining and petrochemicals industries--and Tate and Billheimer (1967)--the aluminum industry--on the detrimental impact associated with a rapid shutdown of those respective industries has important implications for postattack recovery. Van Horn and Crain's (1975) study of the process control industry from both a supply and demand standpoint underscored potential problems in an industry in which, from a supply standpoint, important inputs are derived in large measure from two regions of the country and in which, from the standpoint of demand, rapid technological advances potentially increase the vulnerability of control measures in industries using electronic process control devices.

A study by Miller and Stratton (1980) on the petroleum industry provided one of the many substitution possibilities that are feasible in a postattack economy. Their recommendation for use of an expedient crude oil unit to produce diesel fuel would substantially reduce the amount of time that it would take to make diesel available in the postattack economy. Similarly, conventional and unconventional substitution possibilities for electric power discussed by Foget and Van Horn (1969) could potentially ameliorate some of the electric power problems in a postattack economy. Many of the other studies of individual industries that are presented in Chapter 5 illuminate both problems and potential

solutions in specific industries of the postattack economy that are beyond the capability of input-output models to embody.

As the state of the art in economic recovery modeling progressed, many modelers saw the need to relax the assumption of fixed production coefficients. A refinement to the fixed production technology approach was the introduction of production functions that relate output in individual sectors to the use of capital and labor. More recent refinements include the use of endogenously determined input-output relationships that are based on the level of surviving resources after a hypothetical attack on the economy. Recognizing the deficiencies inherent in simulating the performance of the economy on the basis of surviving physical resources alone without consideration of economic institutions, the most recent attempts at modeling the postattack economy have involved a system dynamics approach in which, among other factors, managerial, fiscal, monetary, and psychological factors potentially impinging on economic recovery were incorporated in the modeling system.

Hill and Gardiner (1979), for example, used a system dynamics approach to address the question of whether economic recovery was automatic or whether the governing authority played an instrumental role in the performance of the postattack economy. The results suggest that adequate surviving industrial capacity <u>per se</u> is not sufficient for economic recovery. Emergency preparedness activities and resource management actions are important factors in economic recovery. In another study using a system dynamics approach, Peterson et al. (1980) incorporated psychological responses in their formulation of a postattack recovery model. Based on the simulation of a number of different scenarios, the authors concluded that there was a "threshold" of damage wherein the psychological response of the population thwarts economic recovery.

To varying degrees, the specification of system dynamics models to ascertain the recovery potential of the postattack economy has included many of the institutional features of the economic system that typically are not incorporated in economic models. That is, there are a number of implicit assumptions that typically underlie the formulation of an economic model. These assumptions--whether made explicit or not--deal not only with the physical infrastructure of the economy, but the institutional infrastructure as well. It is implicitly assumed that there is a viable medium of exchange in existence to facilitate market transactions. It is also assumed that there is an established system of property rights and a legal system that guides economic activity. It is assumed that the primary method used for the allocation of resources is the market mechanism--the interaction of market forces. It is assumed that a system of incentives as embodied in the tax system is well established. Moreover, it is assumed that incentives exist for the production of goods and services--a profit motive--and there are incentives for human capital to be offered in labor markets. With respect to the latter point, the implicit assumption is that a sociocultural system has evolved over the years that both guides individual behavior and complements the functioning of the economic system.

Clearly, there is a large difference between (a) the use of economic models to simulate the activity of the physical economic infrastructure--land, labor, capital, and material inputs--in an environment where all of the institutional features of the system are well-established and operative over a number of years and (b) the use of economic models to simulate an economy in which political, economic, and social institutions are either destroyed or seriously impaired. Simulation of economic activity in the latter context must necessarily incorporate explicit representation of all of the political, social, and economic institutions--and their interrelationships--to determine the economic recovery potential of the postattack economy. Or, alternatively, combining drastic changes in <u>both</u> the physical and institutional arrangements in the economy lead to a large number of possible outcomes that are quantitatively unpredictable.

The importance of this latter point has not gone totally unnoticed in the literature on postattack economic recovery. As discussed in Chapter 6, Dresch and Ellis (1966) undertook a detailed systems analysis study of the interactions between the sociocultural, political, and economic subsystems of the national entity to isolate potential problems that may impinge on postattack recovery. On a <u>qualitative</u> basis, they identified inputs to and outputs from each of the subsystems that characterize the national entity. Although they recognized that a <u>quantitative</u> model depicting the interrelationships between various components of the national entity would provide valuable insights into the operation of the postattack economy, data limitations proved prohibitive. On the use of a model to characterize the functioning of the national entity and prospects for economic recovery, Dresch and Ellis observed:

> Although systems analysis has been used (in this study) to arrange these inputs into a frame of reference, it seems clear that no model or simulation, however vast, could usefully encompass or faithfully distill the essence of the whole U.S. society. (Dresch and Ellis, 1966, p. 13).

The implications of Dresch and Ellis' assessment of modeling the postattack recovery potential of an economy in which there is serious impairment in the functioning of all strata of the national entity are quite clear.

Based on examining the research contributions on the physical infrastructure of a postattack economy, three conclusions relating to postattack recovery emerged. First, the level of potential destruction of economic resources under hypothesized attack scenarios has been defined. Second, partially as a result of the first, potentially significant problems in harnessing surviving resources into a viable productive economy have been detailed. Third, the economic conditions--in a conceptual sense--under which recovery is likely to occur have been demonstrated. These conditions were discussed by Winter (1963):

> In aggregative terms, the process of achieving viability can be viewed as a race between the reconstruction of the capital stock (and thus the recovery of output) and the depletion of

> the inventories from which essential needs are being met in the meantime. (Winter, 1963, p. vi).

There has been no definitive quantitative statement on economic recovery to complement Winter's qualitative assessment of the recovery potential of the U.S. economy. The quantitative assessments of economic recovery that have been presented in the literature are merely suggestive of recovery potential if the institutions that guide productive activity do not impede economic performance. These institutions are the subject of the next section.

ECONOMIC INSTITUTIONAL INFRASTRUCTURE

In general, as in the case of studies of the physical infrastructure of the economy, the majority of prior research on institutional issues has been concentrated on recovery from large-scale disasters that are the result of hypothesized nuclear attacks. However, in contrast to prior research on the physical infrastructure, there has been relatively little substantive research undertaken on issues related to the institutional infrastructure of the economy in the aftermath of a disaster. The importance of that gap in the literature has been underscored over the past three decades by numerous contributing authors on the subject of postdisaster economic recovery.

For example, Cavers (1955), writing in the early years of the nuclear age on institutional issues associated with nuclear war, concluded:

> . . . the problem (of nuclear attack) has been unfortunately conceived largely in terms of physical arrangements. Even the most far-reaching of our non-military defense planning efforts, Project East River, devoted virtually no attention to problems of legal and economic organization. Indeed, of its 263 recommendations, only one in my opinion fits into this category. . . (Cavers, 1955, p. 131).

Furthermore, in their extensive research on the vulnerability of the nation as an entity to nuclear attack, Dresch and Ellis (1966) stated:

> . . . some of the most important effects of a massive attack may not come from the direct effects on property and capacity but from the indirect effects on institutions and attitudes. (Dresch and Ellis, 1966, p. 11)

In assessing the research undertaken on the postattack economy, Dresch and Ellis concluded:

> Past studies of industrial and economic vulnerability have gone into detail in the analysis of surviving capacity, the requirements for repair, conversion, and reconstruction of capacity, the allocation of facilities and other resources, and the feasibility of meeting alternative schedules for econ-

omic support and recovery. The attention devoted to institutional and organizational aspects of recovery management, however, has been hopelessly limited. (Dresch and Ellis, 1966, p. 117).

Finally, in their study of prospects for recovery from nuclear attack, Greene, Stokley, and Christian (1979) concluded in part:

> The major unanswered questions deal with human behavior, social and political disorganization, and the restoration of a functioning economy--all questions not of physical resources, but of 'management.' (Greene, Stokley, and Christian, 1979, p. v).

Most of the emphasis in the literature on institutional issues associated with relatively small-scale, localized disasters resulting from natural phenomena has been on damage compensation in the aftermath of disaster. Concisely, the majority of contributors to the literature have argued that a comprehensive system of disaster insurance is, from an economic perspective, much preferred to the present *ad hoc* approach of compensating for losses attributable to natural hazards.

With respect to economic institutional issues in the aftermath of a nuclear disaster, published research has been, almost without exception, speculative or superficial, generally lacking an analytical basis. Indeed, one of the primary recommendations advanced by contributors to the literature on the postattack economy has been the need for more rigorous analysis of institutional issues--organization and stabilization measures, monetary reform, a system of taxation, and war damage compensation.

What is clearly needed in the area of economic institutional planning is a research effort to integrate all of the organizational, monetary, and fiscal tools that are at the disposal of all levels of the government. Integration is required to ensure that economic planning is consistent. Besides resolution of the myriad problems associated with entangling legal arrangements that existed prior to a large-scale disaster, a coordinated effort must be made to resolve all of the organizational, monetary, and fiscal problems attendant with a large-scale disaster.

To illustrate this principle of coordination, it is clear that, from an equity and production incentives standpoint, a system of damage compensation must be developed and integrated with the fiscal system or, alternatively, an extra-tax program of damage compensation must be developed that is consistent with the fiscal program. The program of damage compensation, therefore, must be coordinated with the approach that will be used for Federal revenue generation. This is no less true for a currency reform which must be part of a system of overall monetary policy in the postattack recovery effort.

Although there are no perfect historical analogues for the potential economic problems that a nation will confront in the aftermath of the large-scale destruction of human and physical resources and the im-

pairment of economic institutions, the experiences of countries that underwent reconstruction after World War II (Germany, for example) suggest some of the economic problems that an attacked nation may confront. What is apparent from the economic stagnation experienced by Germany in post-World War II reconstruction is that economic policy was improperly devised. The result was a degree of economic stagnation that could have been ameliorated with implementation of an economic reconstruction program that relied less on direct controls and central administration and more on the market mechanism.

In Germany, a policy of repressed inflation in concert with a host of commodity controls that superceded the market mechanism led to economic stagnation and reversion to an exchange system that only partially involved the use of the prevailing currency. The economic reforms initiated in June of 1948 that revalued the currency, lifted direct controls, and revised the tax system led to a dramatic reversal in economic productivity.*

Stagnation of the German economy was attributable to three interrelated factors. First, the occupying powers continued a very rigid system of wage and price controls that was carried over from the German wartime economy. Second, earned income was taxed heavily. Third, the authorities failed to eliminate the enormous amount of excess purchasing power that was present in the economy.

Perhaps the most important manifestation of these economic policies was their effect on incentives--incentives both to produce and work. With respect to production incentives, a rigidly controlled system of absolute and relative prices in concert with other factors that characterized the German postwar economy--declining labor productivity and shortages of raw materials, for example--did not afford adequate compensation for output. Thus, there was no incentive to produce at prevailing price levels. The lack of incentive to produce led to shortages of consumer goods. The lack of consumer goods in concert with excess liquidity in the economy offered no incentive for the work force to offer their services in the labor market. Money compensation, in general, was not sufficient to attract labor in an economy where consumer goods

---

*A caveat must be added when attributing Germany's dramatic economic turnaround wholly to reforms initiated in June of 1948. Many authors have pointed out that other factors may have contributed to the economic stagnation prevalent in the immediate postwar period. Hirshleifer (1963), for example, pointed out that, besides the policy of repressed inflation, there were two other organizational forces at work in Germany in the immediate aftermath of the war--restrictive economic policies of the Allies and social and political disorganization. Hirshleifer argued, however, that these two forces were secondary to the policy of repressed inflation in explaining Germany's stagnation: " ... the analysis here indicates that social and political disorganization was not too significant as an independent factor after the crisis of 1945, while the economic disorganization caused by the lack of an effective monetary mechanism persisted until the reform." (Hirshleifer, 1963, p. 111).

were not available and there was already an excess amount of purchasing power.

The extant literature on economic organization and stabilization in the postattack economy has addressed the spectrum of control and stabilization possibilities. There are at least three major themes that permeate the literature on economic control in the event of a large-scale nuclear disaster. First, most authors have stressed the importance of economic management in the recovery process in the early aftermath of a nuclear disaster. Second, a theme that also runs through the literature is that the Federal government's plan for controlling the economy is inadequate. For the Federal government to take any kind of active role in directing the economy, much more preparation will have to be undertaken in the preattack period. Finally, with respect to the Federal government's current planning, too much emphasis has been placed on the types of control measures used to direct economic activity in the American economy during World War II. Alternate control measures must be developed.

What is readily evident from a study of the various scenarios resulting from a large-scale disaster is that the Federal government cannot assume the role of "invisible hand" in economic recovery. That is, the allocation of economic resources that, for the most part, is made by innumerable decentralized decisions in the preattack economy cannot be superceded by a system in which the central authority makes all of those decisions. There are at least two important reasons for this assertion.

First, resources needed for effective central management of the economy more than likely will not be available. The lack of management resources is attributable to both the likely destruction of centers of government and the amount of managerial resources required for making resource allocation decisions in an economy as complex and as potentially imbalanced as the postattack U.S. economy. Even if the political authority of the federal government were reestablished, centralized control of economic decisions would necessitate an enforcement cadre that extends well beyond the bounds of likely surviving resources.

Second, the size of the resource management base notwithstanding, the Federal government does not have the experience, expertise, or information to assume all of the decentralized decision-making that characterizes a market-oriented economy. For example, it is anticipated that one of the most important stimulants to recovery--at least in the early postattack recovery phase at the local level--will be reliance on unconventional or expedient production processes that will circumvent the need for some types of productive inputs that were used preattack. The localized nature of these activities is conducive to on-site--and not governmental--implementation. Therefore, even if all of the managerial resources of the Federal government survived a large-scale disaster (because of extensive preattack measures to ensure survival, for example) and other institutional arrangements were reestablished to provide the proper economic incentives (an effective currency, for example), the capability of a central authority to control a damaged, market-oriented economy is limited.

Several contributors to the literature on postattack economic recovery have argued that nationalization of all economic resources and consequent centralized control of economic activity for at least a short period of time in the recovery effort may be desirable because, if effectively administered, it would eliminate many of the other institutional problems in the postattack economy. For example, if the allocation of all producer and consumer goods were accomplished through central administration, the requirement for currency reform would be less compelling because markets would be superceded and currency would not be required to facilitate exchange. Economic activity would proceed on the basis of government proclamation. The two aforementioned arguments on the level of surviving managerial resources and the expertise to control the economy are applicable here. Reliance on a policy of nationalization and control for a limited time in the immediate postattack period is even less appealling if one assumes that the most critical period of the recovery effort is in the early stages of reorganization when emphasis is placed on rebuilding the capital stock.

If central control of economic resources is eliminated from consideration as nonworkable or inefficient, presumably some form of a market mechanism will guide economic activity at all levels without reliance on the government for allocation of resources. Under this assumption, the role of the Federal government in economic stabilization must be delineated. That role, of course, is a direct function of economic problems that are likely to arise in the postattack environment. One of the most important problems is the distortion of relative prices that guides economic activity in a market economy. Some authors have maintained that wage and price controls are the solution to the anticipated problem of wild price fluctuations. Assuming that an effective currency reform can be implemented, it is questionable whether wage and price controls are advisable in the postattack economy.

There are several compelling reasons for this assertion. In order to be effective and prevent reversion to barter, a system of wage and price controls must match legal price ceilings with realistic prices determined by the relative availability of surviving resources. In peacetime use, price ceilings for controlled goods are established and then periodically adjusted to reflect cost increases. In wartime (the U.S. economy during World War II, for example), price controls were the manifestation of the need to direct a large amount of economic resources into the production of war-related goods at the expense of consumer goods. Rationing of consumer goods was imposed as a result of their relative scarcity and, to prevent rapid increases in the level of prices, price ceilings were imposed on a number of consumer goods. An elaborate price control administration was in existence to develop legal prices consistent with current market conditions.

These applications in an undamaged economy can be differentiated from what would be expected in the postattack economy because of the lack of information on realistic relative prices. That is, a large-scale and disproportionate destruction of resources would cause a drastic alteration in realistic relative prices from what prevailed in the preattack economy. Any attempt to freeze prices at preattack levels for any period of time would result in a serious distortion of relative

prices. Moreover, because of lack of finely detailed information on the destruction of resources, substitution possibilities, and the pace of recovery in individual sectors of the economy, it is improbable that the Federal government could determine a legal set of prices that would be consistent with realistic prices based on prevailing conditions in the economy.

The economic consequences of a failure to match legal and realistic prices is well documented. In Germany, for example, the occupying powers continued a system of price controls established by the Nazi regime. Relative prices in the aftermath of the war were nearly the same as those set a decade earlier in 1936. This distortion in relative prices led to shortages of important commodities because of the disincentive to produce at legal price ceilings that only partially covered the costs of production.

Given the nonviability of wage and price controls, what is needed is a comprehensive research effort to explore various options for providing price signals in a disproportionately damaged economy. More than two decades ago, Winter offered some unconventional suggestions for dealing with this problem during his participation in the Project Harbor study [see National Academy of Sciences (1963)]. For the most part, those suggestions were conceptual alternatives to a system of wage and price controls. The potential solutions advanced by Winter were (a) advisory prices developed by the government and based on some form of damage assessment, (b) a futures market for essential commodities, or (c) a system of select price guarantees. All of the proposals advanced for consideration were intended to provide realistic price signals in a market economy to guide investment behavior.*

The role of the Federal government in economic recovery outside of the development of a contrived market mechanism is also important. Many authors have argued that an elaborate system of commodity controls must be established to ensure that important inputs into production are directed to their most essential uses. Here again, the problem of information available at the smallest level of detail--the individual plant level, for example--is a constraining factor. The fundamental question is whether the Federal government has the information available to make efficient resource allocation decisions. The level of information required is at the individual input level and requires knowledge of, among other things, inventories, substitution possibilities, and investment expenditures.

Several authors have advocated the development of an information system which would provide the Federal government with information necessary to control the economy. Dresch (1964), for example, developed an elaborate master scheduling system that would direct investment decisions and material flows in the postattack recovery effort. The pro-

---

*For a detailed analysis of postattack markets, see Cantor, Henry, and Rayner, Markets, Distribution, and Exchange after Societal Cataclysm, Oak Ridge National Laboratory, Oak Ridge, Tennessee, ORNL-6384, 1987, Forthcoming.

posed scheduling system would require the federal government to decide priorities for production with the assistance of 509 regional institutions established to provide information for the master plan. However, upon further reflection, Dresch (1968b) abandoned the idea of a master scheduling system because of its unwieldiness in the early postattack recovery period where it will be essential for investment decisions to be made on a timely basis.

With respect to monetary reform, nearly all commentators have emphasized the need for a program to prevent reversion to barter. The importance of a currency reform to adjust the level of liquidity in the economy in the wake of a disaster is well documented. In Germany, for example, the authorities pursued a policy of repressed inflation. Under this policy, excess purchasing power in the economy did not result in rapid increase in prices because wage and price controls were imposed. Had the authorities abandoned the system of price controls without monetary reform, the economy would have experienced a period of rapidly increasing prices. The currency reform of June 1948 adjusted the liquidity in the economy to match the available supply of goods and, therefore, a balance between the monetary and real economy was attained.*

To resolve potential monetary problems in the postattack economy, a number of authors have espoused a currency reform--the so-called "blue money" proposal--in which a new scrip would be issued to replace the preattack currency at an exchange rate sufficient to eliminate excess liquidity and, therefore, the potential for rapid inflation. Other authors have discussed the need to back the new currency with an important postattack commodity--gold, food supplies, or petroleum products, as examples--to ensure its functioning as a medium of exchange. Other authors have argued that multiple currencies should exist (at the state or Federal reserve district level, for example) because of the possibility of a lack of confidence in a national currency.

It is evident that a policy of stockpiling the preattack currency for use in the postattack economy is not consistent with the solution of one of the most important potential problems in the economic recovery effort--the control of financial liquidity in the face of the disproportionate destruction of real and monetary resources. A more effective approach would be to stockpile a new scrip--the so-called "blue money"--to be used as part of a currency reform early on in the postattack economy.

In the postattack economy, the tax system is a crucial factor in at least two important areas. First, it has an obvious importance in directing expenditures from current consumption to savings. The

---

*It must be emphasized that the excess liquidity in the German economy during the Allied occupation in the aftermath of the war was the manifestation of years of economic controls imposed by the Nazi regime. In the postattack recovery context, the potential for a liquidity problem is caused by the potential for disproportionate destruction of real goods and purchasing power. However, the economic implications in both cases are similar.

savings, of course, are utilized to finance investment in plant and equipment that will be used to increase future levels of consumption. The second area where taxes play a prominent role is in the postattack incentive system. In Germany, for example, high levels of taxation in concert with excess liquidity in the economy proved to be a disincentive for working.

Perhaps no aspect of postattack economic recovery has elicited more divergent views than those associated with the tax system. Conjecture has varied from using the tax system as a means to redistribute surviving wealth--a damage compensation system--to using it as a vehicle to absorb excess purchasing power. Although a number of different types of taxes have been offered for consideration (national sales tax, value-added tax, progressive income tax, estate tax, capital gains tax, and a tax on wealth), a comprehensive program of taxation that is consistent with other institutional measures has not been offered in the literature.

An important disagreement in the literature has been on the use of steeply progressive income taxes. On the one hand, it has been argued that progressive taxes, among other characteristics, offer a viable means to redistribute wealth. On the other hand, it has been argued that progressive taxes would stifle economic growth; thus, the redistribution of wealth should be handled outside of the tax system.

Authors contributing to the literature on a postattack system of taxes have in general pointed out the need to use the system for directing resources into investment and away from consumption goods. Dresch, for example, argued that a tax system, if devised properly, could contribute to eliminating excess purchasing power by diverting income from current consumption into savings. His proposal of forced savings would attach a tax surcharge on every taxpayer beyond the level of normal withholding for Federal revenue generation. The additional tax withholding would reduce current purchasing power and would be used for investment purposes. The tax surcharge would be used by individual taxpayers to purchase investment certificates that could be converted into various public and private securities to help finance the recovery effort. The program would be eliminated after the economy was back on a long-run recovery path.

RECOMMENDATIONS

Four areas have been identified which, if addressed, could significantly improve planning for economic recovery in the aftermath of a disaster. First, attention must be devoted to isolating problems and developing control measures in the event of a prolonged nuclear conflict. Second, research should be undertaken to develop an organization and stabilization program consistent with approaches to fiscal and monetary reform and damage compensation in a severely damaged economy. Third, as an extension of research undertaken over the past two decades, several key industries should be the subject of more intense scrutiny. The most prominent of these are the transportation and process control industries. Fourth, an increased emphasis must be placed on problems and op-

portunities associated with the international economy in the aftermath of a large-scale nuclear disaster.

A scenario of prolonged nuclear conflict and its attendant economic problems cuts across all facets of planning for economic recovery--economic stabilization, individual industry performance, and international effects. However, little substantive research has appeared in the literature which addresses organization and stabilization problems in an economy increasingly fragmented over a period of months and how these problems differ from those that would arise in a less extended conflict.

The most important problem in postattack economic recovery planning is development of a consistent program encompassing all of the economic tools at the disposal of the government to ensure the proper environment for productive economic activity. The preceding discussion delineated (a) the potential managerial, fiscal, and monetary problems that are likely to arise in a postattack economy; (b) the problems encountered with economic control devices used in the severely damaged German economy after World War II; and (c) possible solutions to postattack economic problems. A research effort is required that provides a detailed array of possible approaches to stablization, monetary, fiscal, and damage compensation problems, along with their strengths and weaknesses. The research should attempt to develop a consistent approach for all economic reform measures. It should not be limited exclusively to Federal reform but should encompass subnational jurisdictions as well.

Studies of individual industries have isolated many problems that may arise in key industries as a result of a generalized disaster. The studies provide a sound basis for planning and developing corrective programs for recovery. However, among the many industries that are critical for recovery, there are two industries which warrant further detailed study--transportation and process control. A series of studies at the Stanford Research Institute in the 1960s encompassed the vulnerability and viability of all of the transport modes. Because of changes in both the transport resource base and the strategic threat over the past two decades, however, the studies are somewhat outdated. In the "islands" or "pockets" of survival context, transportation looms as one of the most important service industries. With respect to process control, Van Horn and Crain's (1975) study of the industry from both a supply and consumption standpoint illuminated the potential severity of problems that could arise as a result of a generalized nuclear disaster. From the standpoint of supply, geographical concentration of important inputs used in the industry poses significant problems for recovery. From the standpoint of demand, rapid improvements in--and penetration of--technology used for industrial process control systems increasingly contribute to the vulnerability of industrial control processes and, hence, industrial output.

No important topic relating to postattack economic recovery has been overlooked more than the international economy. Many studies have alluded to the potential importance of foreign sources of supply to ameliorate bottlenecks, for example, but no study has specifically focused on supply sources and problems that may be encountered in obtaining vital imports. International considerations take on increased im-

portance because of the likelihood that many economies throughout the world will not be directly affected by the disaster. Potential problems include restrictions on international transport and the reluctance of foreign governments to trade. Additionally, a question of critical importance is the effect of a global nuclear conflict on the international monetary system in general and the U.S. dollar in particular. A research effort that addresses these potential international problems is a necessity in the context of planning for domestic economic recovery.

1. INTRODUCTION

The purpose of this study is to analyze, synthesize, and assess the extant literature on postdisaster economic recovery in the context of providing a background for policy development. The magnitude of disasters under consideration is all-inclusive. Therefore, economic recovery from relatively localized disasters resulting from natural phenomena--earthquakes, floods, and tornadoes, for example--is considered as well as economic recovery from a generalized disaster resulting from a hypothetical nuclear attack.

It must be emphasized that, with respect to a hypothetical generalized disaster, only studies associated with some aspect of economic recovery from the disaster are considered in the report. Therefore, research undertaken on strategic and military considerations, continuity of government issues, and the physical, biological, and meteorological effects of the disaster are beyond the scope of the present study. However, concomitant with this study, there were a number of more specialized studies conducted at Oak Ridge National Laboratory that deal with other aspects of recovery. Those studies include the effects of radiation on land, the provision of postattack shelter, the provision of emergency food and water, and a study of national security food requirements.*

For purposes of the present study, the U.S. economy has been divided into two broad components--the physical infrastructure and the institutional infrastructure. The physical infrastructure is comprised of factors of production or, alternatively, all tangible resources used in the process of producing goods and services. It includes land, labor, capital, energy, and other tangible inputs in the production process. The institutional infrastructure, on the other hand, encompasses the environment in which productive economic activity occurs. It can be viewed as the established social, political, and economic arrangements that facilitate and coordinate economic exchange. Economic institutional issues include the organization and stabilization of the economy in concert with other monetary, fiscal, legal, and social arrangements that provide the environment for productive activity.

---

*C.F. Baes III, C.T. Garten, Jr., F.G. Taylor, and J.P. Witherspoon, The Long-Term Problems of Contaminated Land: Sources, Impacts, and Countermeasures, Oak Ridge National Laboratory, Oak Ridge, Tennessee, ORNL-6146, November, 1986; C.V. Chester and G.P. Zimmerman, Civil Defense Shelters: A State-of-the-Art Assessment--1986, Oak Ridge National Laboratory, Oak Ridge, Tennessee, ORNL-6252, Forthcoming; D.J. Bjornstad, F. Paul Baxter, and Sterling Hobe Corporation, Emergency Food Delivery: A State-of-the-Art Assessment, Oak Ridge National Laboratory, Oak Ridge, Tennessee, ORNL-6257, Forthcoming; A.H. Voelker, The Provisioning of Water in Emergencies: A Research Assessment, Oak Ridge National Laboratory, Oak Ridge, Tennessee, ORNL-6203, September, 1986; and C.R. Kerley and S. Das, Issues and Options for Achieving National Food Security in the United States During National Emergencies: Phase I, A Pilot Study of Grain Stocks and Stocks at Risk, Oak Ridge National Laboratory, Oak Ridge, Tennessee, ORNL-6256, Forthcoming.

In the literature on generalized disasters, the aftermath of nuclear attack has been typically characterized in stages--defined somewhat arbitrarily on a temporal basis--that reflect priorities in the recovery effort. One characterization divides the period following nuclear attack into a population maintenance phase, a reorganization phase, and a recovery phase. Population maintenance refers to the period of time in which the majority of effort is devoted to ensuring the long-term survival of the remaining population. Important activities during this phase are the provision of essentials required for existence--food, shelter, and clothing. The reorganization phase is the period of time in which surviving resources and institutions are reshaped to resume productive activity. The recovery phase refers to the resumption of economic activity at a level consistent with surviving resources.*

Using the population maintenance-reorganization-recovery characterization of the postdisaster economy, emphasis in this report is placed on the economic reorganization and recovery phases. The primary reason for this focus is the aforementioned research undertaken at Oak Ridge National Laboratory which has as its main thrust issues associated with the population maintenance phase in the aftermath of a generalized disaster. Also, very little attention is devoted to economic issues associated with the period preceding a generalized disaster--crisis relocation, for example. Population maintenance and crisis relocation issues are considered only to the extent that they were included in prior studies on multiple aspects of postattack recovery.

The report is divided into eight chapters. Besides an introduction and a concluding chapter, there are six substantive chapters. Chapters 2 through 5 and Chapter 6 present research results on the physical and institutional infrastructures, respectively. Chapter 7 provides an assessment of the research presented in the preceding five chapters.

Both the discussion of the physical and institutional infrastructures are organized in a hierarchical manner. That is, they are introduced with a summary of the methodology and research results at the beginning of the discussion. For the physical infrastructure, Chapter 2 provides the summary. The beginning of Chapter 6 contains the summary of research on the institutional infrastructure. The synopsis of prior research at the beginning is intended to provide the interested reader with an overview of research approaches, scope, and results. The remainder of the discussion on the two components of the economy provides a more in-depth analysis of prior research in the respective areas, highlighting the contributions of individual studies.

The organization used to present prior research on the physical infrastructure in Chapters 2 through 5 was dictated by the methodology and scope of prior research. That is, besides the summary of the research in Chapter 2, the discussion is organized on the basis of (a) studies of the national economy in Chapter 3--further divided between studies using

---

*Another characterization of the aftermath of nuclear attack that is somewhat similar includes a reconstitution phase, a recovery phase, and a reconstruction phase.

formal economic modeling approaches and nonmodeling methods; (b) studies of regional or local economies in Chapter 4--again divided between studies using modeling approaches and nonmodeling methods; and (c) individual industry studies in Chapter 5, which include studies of aluminum, rubber, steel, chemicals, drugs, construction, transportation, petroleum, natural gas, and electric power.* No distinction is made in the classification between studies of economic recovery from geographically localized or generalized disasters. However, the distinction is obvious from the content of the research.

The presentation in Chapter 6 on the institutional infrastructure is organized around four critical issues in the postdisaster economy: (1) economic organization and stabilization; (2) the monetary system; (3) the fiscal system; and (4) damage compensation. Here again, no distinction is made in the discussion as to the type of disaster under consideration. However, the majority of research on institutional issues associated with natural disasters has been concentrated on damage compensation or, more specifically, a program of comprehensive disaster insurance. The presentation in Chapter 6 concludes with a discussion of a historical analogue--the economic reconstruction of Germany following World War II--that is used to isolate issues that are important for recovery in a disrupted economy. Although it is recognized that there is no perfect historical analogue for the extent of likely damage and disruption in the aftermath of nuclear attack, the discussion is suggestive of the economic problems that may arise as a result of policies adopted in reconstructing a seriously damaged economy.

To a large extent, the discussion of Germany in Chapter 6 is used as a reference point for the assessment of prior research on the institutional infrastructure presented in Chapter 7. In Chapter 7, a schematic representation of the U.S. economy is also presented to help identify and assess the major thrust of prior research on both the physical and institutional infrastructures of the postdisaster economy. Besides the conclusions drawn from the study, Chapter 8 presents some recommendations which, if acted upon, could significantly improve planning for economic recovery in the aftermath of a disaster.

---

*Note here the absence of the food production and processing industries which are instrumental in the population maintenance phase of recovery. Issues associated with those industries are included in other research on economic recovery.

2. OVERVIEW OF STUDIES OF THE PHYSICAL INFRASTRUCTURE

2.1. INTRODUCTION

As discussed in the introduction, the U.S. economic system is characterized in this study as consisting of two broad subsystems--the physical infrastructure and the institutional infrastructure. The purpose of this chapter is to provide an overview of published research on the physical infrastructure of both the national economy and regional economies in the aftermath of a disaster.

The presentation of prior research on the physical infrastructure of the economy is hierarchical in the sense that a summary of prior research--including the scope of research and identification of common themes--is presented in this chapter, while a more detailed examination of individual research efforts highlighting the contributions of individual studies is presented in the following three chapters. The presentation of research in the following three chapters has been divided into three broad categories reflecting the scope of the extant literature: (1) studies of the national economy in Chapter 3; (2) studies of local or regional economies in Chapter 4; and (3) individual industry studies in Chapter 5. For Chapters 3 and 4, the discussion is further divided into studies using formal economic models and studies using nonmodeling methods.

The classification used for presenting research in the following three chapters is not intended to define precisely the geographical scope of the disasters under consideration. That is, although all of the studies categorized as "studies of the national economy" are related to some aspect of the economy after a hypothesized large-scale nuclear attack as opposed to the national consequences of a regional disaster, not all of the regional studies are limited to examining the effects of geographically localized disasters. Many of the studies of damaged regional or local economies are discussed within the context of a much broader nuclear attack scenario. The emphasis of these analyses, however, is on the reconstitution and recovery of one specific geographical area. Moreover, although studies of individual industries were generally undertaken in the context of hypothetical nuclear attack scenarios, many of the studies--whether implicitly or explicitly acknowledged--also pertain to the effects or threat of more geographically localized disasters.

For studies using economic models on a national or regional level to simulate the performance of the postdisaster economy, it is not the purpose here to provide an overview of all economic models that <u>potentially</u> could be used for that purpose. Rather, the focus is on modeling systems that have been constructed or used to simulate postdisaster economic performance and the results of which have been documented in the literature.

Since emphasis is placed on the results of the studies on questions such as the viability of the economy in the aftermath of a hypothetical disaster and the potential impediments to recovery, an important issue

is the relevance of past studies to present conditions. The problem is particularly acute because the majority of studies of economic viability or recovery in the aftermath of a disaster have been conducted in the 1960s and early 1970s. Clearly, the economic structure of the economy and, in the case of a generalized disaster, the nature of the nuclear threat have changed substantially since the majority of the studies were undertaken.

The purpose of the present study is not to conjecture on the applicability of the results of prior studies for the present time, but rather to delineate and assess methodologies that have been used to address some aspect of the economic recovery question. In Chapter 7, the results are evaluated in the context of the methodologies employed--not necessarily in the context of their applicability to economic and national defense conditions that exist at the present time.

2.2. STUDIES OF THE NATIONAL ECONOMY

Table 2.1 provides a list of the studies of the national economy using economic models--categorized by corporate contractor--that are discussed in detail in Chapter 3. While all of the contributions listed in Table 2.1 involved the construction of formal models of the national economy, some of the published works did not present simulation results. In those cases, the primary purpose of the reports was to document a modeling approach that could be used to simulate some aspect of the postattack economy. These studies include Wetzler, Dolins, McGill et al., and Decision Science Applications.*

The studies embraced a wide array of issues associated with postdisaster economic recovery. Although somewhat of an oversimplification, the purposes of the studies listed in Table 2.1 can be categorized into four broad areas: (1) determination of the conditions for postdisaster recovery; (2) analysis of some measure of performance of the postattack economy; (3) analysis of the effect of various Federal policies on postdisaster recovery; and (4) analysis of the effectiveness of various types of military and nonmilitary defense measures that could be undertaken in the predisaster period to ameliorate the potential physical effects of nuclear weapons.

In the first area, Winter provided the conceptual conditions under which an economy could recover from nuclear attack. Succinctly, he characterized the recovery effort as a "race" between the depletion of vital inventories and the replenishment of productive capacity. The primary purpose of the studies in the second area was to determine in quantitative terms the performance of some aspect of a damaged economy. Included among the measures were estimates of postattack gross output, the determination of bottlenecks or constraining sectors in the economy, and the number of people that could be supported by the surviving resources of the economy. Several of the studies also dealt with aspects of how specific resources are measured and their effect on simulation

*For Decision Science Applications (1983), simulation results were presented for the Soviet economy.

Table 2.1.
Individual Studies of the National Economy
Economic Models

Institution	Author(s)	Date
The Rand Corporation	Clark*	1958
	Bear and Clark	1960
	Massell and Wolf	1962
	Winter	1963
Engineering Strategic Studies Group	Wright and Smith	1965
Institute for Defense Analyses	Peskin	1965
	Bickley, Crane, and Pearsall	1968
	Pearsall	1968
	Wetzler	1970
	Dolins	1970
	McGill et al.	1972
Stanford Research Institute	Allen	1968
	Allen	1969
	Lee	1968b
	Lee	1968c
	Lee	1969
	Lee	1970
	Baum and Dresch	1971
	Dresch and Baum	1973
Arms Control and Disarmament Agency	Strell	1968
Research Analysis Corporation	Sobin	1968b
	Sobin	1969
American Technical Assistance Corp.	Bull	1973a
	Bull	1973b
Federal Preparedness Agency	Pettee	1978
Analytical Assessments Corp.	Hill and Gardiner	1979
Pugh-Roberts Associates	Peterson et al.	1980
	Peterson et al.	1981
Decision Science Applications	Decision Science Applications	1983
Battelle Pacific Northwest	Belzer and Roop	1984

*Contained in Kahn et al. (1958).

results. Wright and Smith, for example, contrasted the performance of the economy by using different measures of capacity in an input-output framework.

The focus of studies in the third area was the analysis of some of the policy options of the federal government and/or the private sector and their effect on economic recovery. The most prominent of these options was investment in specific sectors of the economy to alleviate bottlenecks. The fourth broad area of research addressed types of preattack defensive measures that could be taken to mitigate economic problems in the aftermath of an attack. These measures were both military-related (the most important resources to defend, for example) and non-military-related (preattack expenditures to "harden" specific economic resources).

Table 2.2 provides a summary of the studies of postattack economic recovery that are classified above as comprising the second, third, and fourth broad areas of research using economic models. The table is intended to provide a broad overview of the primary study purpose, modeling approach, and principal conclusions under the disaster scenarios considered. The table also provides a concise summary of the evolution of modeling approaches from the early, highly aggregated input-output study by Clark to the relatively sophisticated system dynamics approaches of recent years.

Although Table 2.2 shows that the purposes of the studies varied considerably, the approaches used by individual authors to address specific questions were similar. The general approach used in all of the studies was to assume a hypothetical attack scenario or series of scenarios, perform an assessment of damage to the population and economic resources, and incorporate the results of the damage assessment into the formal structure of the model to simulate economic performance. The attack scenarios were either hypothesized by the authors, provided by a government agency, or derived from an optimal targeting model. Damage assessment was accomplished in a variety of ways. The approaches varied from a relatively simple assumption that all of the resources in a targeted metropolitan area were totally destroyed as a result of the hypothetical attack to the use of formal damage assessment computer systems. The results of the damage assessments were typically incorporated into the economic model by reducing the amount of capital and labor available for use in the postattack economy. Labor availability was typically assumed to be available in the same proportion as the surviving population.

The economic models developed for simulating the postattack economy ranged from highly aggregated fixed-coefficient, input-output models [Clark--nine sectors, Strell--six sectors] to relatively sophisticated system dynamics models that determine production relationships endogenously [Peterson et al. (1980), for example]. Apart from the more recent use of system dynamics approaches, the majority of studies used some variant of an input-output model in a linear programming framework. That is, given production interrrelationships between individual sectors of the economy, the procedure was to maximize an objective function given the linear constraints embodied in the production relationships.

Table 2.2
Summary of Modeling Studies of the Postattack National Economy

Author(s) (Date)	Study Purpose	Disaster Scenario	Modeling Approach	Conclusions
Clark (1958)*	Recovery potential	1500 megatons on top 50 metropolitan areas	9-sector I/O	Stockpile; shelter plants
Bear, Clark (1960)	Sectoral demand/supply disequilibrium	Total destruction of 80 largest cities	44-sector I/O	13 of 23 mfg. sectors with excess demand
Wright, Smith (1965)	Comparison of capacity measures	6920- and 10,600-MT attacks	78-sector I/O	Different results with different capacity measures
Peskin (1965)	Effectiveness of industrial protection	Classified	77-sector I/O	Objective function and labor assumption determine results
Bickley et al. (1968)	Recovery potential	Counterforce and countervalue attacks	78-sector I/O	Late 1950s living standard is possible
Pearsall (1968)	Recovery from imbalancing sectoral attks.	Various	78-sector I/O	Can imbalance economy, but recovery feasible
Allen (1968, 1969)	Recovery [illegible] varied defense [illegible]	Various	79-sector I/O	Defensive measures are effective
Baum, Dresch (1971)	Sectoral investment impact on recovery	Various	7-sector I/O w/ prod. functions	Optimal investment facilitates recovery

*Contained in Kahn et al. (1958).

Table 2.2 (Continued)

Author(s) (Date)	Study Purpose	Disaster Scenario	Modeling Approach	Conclusions
Dresch, Baum (1973)	Sectoral investment impact on recovery	Various	15-sector I/O w/ prod. functions	Optimal investment facilitates recovery
Strell (1968)	Recovery potential	1000 one-MT warheads	6-sector w/ prod. functions	86% of preattack per-capita GNP possible
Sobin (1968b, 1969)	Survival requirements	Countervalue attack	82-sector I/O	Small inv. supports 49 million more people
Bull (1973a, 1973b)	90-day recovery under allocation scheme	Countervalue attack	86-sector I/O	Survival essentials met for 1st 90 days
Pettee (1978)	Recovery potential	6000-MT counterforce 6000-MT countervalue	178-sector I/O	Survival in doubt in countervalue scenario
Hill, Gardiner (1979)	Management influence on recovery	Various	4-sector system dynamics	Management of economy influences recovery
Peterson et al. (1980)	Recovery potential under policy options/ psychological response	Various	13-sector system dynamics	Psychological effects and policy important
Peterson et al. (1981)	Examination of natural resource sectors	Various	4-sector system dynamics	Massive sectoral investment is required
Belzer, Roop (1984)	Modification of Peterson et al. (1980)	Various	13-sector system dynamics	Psychological effects and policy important

Typically, gross output was used in the objective function. The input-output framework afforded analysts the ability to ascertain potential bottlenecks in the recovery effort.

Early studies employing an input-output framework characterized the interrelationships in the postattack economy in a manner similar to the preattack economy. This was accomplished by using fixed preattack production relationships to reflect postattack input requirements. Recognizing this limitation in evaluating the postattack economy, several authors placed less emphasis on preattack production relationships. In one of the earliest attempts, Wright and Smith contrasted the results of using preattack production coefficients--maximum degradation of capacity--with a minimum degradation scenario that assumed that not all of the inputs used in preattack production were required postattack. Under the maximum degradation scenario, effective capacity was simulated to be zero--the economy ceases to function--while in the minimum degradation scenario nearly all of the surviving capacity would be effective. In the same year, Peskin concluded that output increases dramatically by assuming increments to capacity through more intensive and extensive use of labor. Later modeling efforts at the Institute for Defense Analyses amended the fixed coefficient assumption by incorporating production functions for individual sectors that established a relationship between labor, capital, and other inputs in the production process. More recent attempts at simulating the postattack economy have attempted to "endogenize" input-output relationships [Peterson et al. (1980), for example].

While nearly all of the studies found limiting factors in economic recovery (individual sectors that could constrain output in an input-output framework, for example), the potential for economic recovery was generally concluded to be favorable in the earlier studies. Bickley, Crane, and Pearsall, for example, concluded that the surviving population after two hypothesized attacks in 1975 would enjoy a standard of living comparable to the late 1950s. One of the attacks they considered was a large-scale countervalue strike in which they estimated that 90 million people and 34 to 41 percent of the capital stock would be destroyed. Bull simulated the economic performance of the economy in the first 90 days after a hypothetical attack in which only 55.7 percent of the population and 34.4 percent of industrial capacity were estimated to survive. Bull's conclusion was that the damaged economy could produce essentials for survival in that period.

Sobin simulated the number of people who could be supported by surviving economic resources after a large-scale, countervalue attack on the United States. His primary conclusion was that a relatively small amount of investment in key sectors of the economy ($295 million at the time) would lead to output that could potentially support an additional 49 million survivors, increasing the total supported population from the original 151 million to 200 million. Dresch and Baum simulated the performance of the economy under a wide range of attack scenarios and under varied assumptions about postattack investment expenditures in different sectors of the economy. The results of their analysis suggested that recovery prospects are favorable and, after the heavier of the simulated attacks, recovery to preattack levels of GNP could occur within a decade.

Pearsall simulated the performance of the economy to ascertain whether it could attain a 1958 standard of living after numerous assumed attacks designed to create bottlenecks in individual sectors of the economy. Although Pearsall concluded that attacks concentrated on individual economic sectors could be devised to thwart economic recovery, he believed that the adverse effects of the attacks could be mitigated by resorting to alternative sources of supply, input substitutions, labor intensive operations, and appropriately applied investment expenditures.

The majority of earlier studies of the postattack economy shared at least one important theme. They were focused on the potential imbalance of production in various industries and demand for the output of these industries. An approach that lends itself well to this type of analysis is use of some variant of input-output analysis. However, this approach assumes that all of the institutional problems of the economy have been resolved. Thus, all of the potential managerial, monetary, and fiscal problems in the aftermath of a generalized disaster have been assumed away. In recognition of this drawback, more recent models of postattack recovery have focused attention on managerial, fiscal, monetary, and psychological problems.

Hill and Gardiner, for example, used a system dynamics approach to simulate whether economic recovery was automatic or whether the governing authority played an instrumental role in economic performance. The results of the simulations over a 24-month period showed that adequate surviving industrial capacity per se is not sufficient for economic recovery. Emergency preparedness activities and resource management actions are important factors in the ability of the economy to recover. In another system dynamics approach, Peterson et al. (1980)* incorporated psychological responses in their characterization of the postattack economy. Based on the results of a number of different simulations, the authors concluded that there was a "threshold" of damage where the psychological response of the population is a limiting factor in economic recovery.

Table 2.3 lists studies of the national economy in the aftermath of disaster using nonmodeling methods. The Laurino, Hanunian, Addington, and two Goen studies examined specific aspects of economic recovery under hypothesized attack scenarios. The two studies by Bickley addressed the concentration of population and essential economic resources. Laurino and Dresch examined the Soviet threat in the 1970s and its implications for recovery from nuclear attack. The two studies by Goen and the Laurino and Dresch study were part of the National Entity Survival Study (NESS) conducted at the Stanford Research Institute in the late 1960s and early 1970s that addressed multiple aspects of the postattack recovery problem.

In general, the results of the studies listed in Table 2.3 showed that prospects for economic recovery from various attacks hypothesized by the authors were favorable. Hanunian, for example, examined eight hy-

---

*As noted in Table 2.., Peterson et al.'s work was subsequently expanded by Belzer and Roop (1984).

Table 2.3
Individual Studies of the National Economy
Nonmodeling Methods

Institution	Author(s)	Date
The Rand Corporation	Hanunian	1966
Stanford Research Institute	Goen et al.	1967
Stanford Research Institute	Laurino	1967
Department of the Army	Addington	1968
Institute for Defense Analyses	Bickley	1968
Institute for Defense Analyses	Bickley	1969
Stanford Research Institute	Goen et al.	1969
Stanford Research Institute	Laurino and Dresch	1971

pothetical attacks that were intended to span the range of plausible attack scenarios at the time of writing. He concluded that recovery prospects were favorable with agricultural production generally outperforming non-agricultural production in the immediate postattack period. Based on examination of several attack scenarios, Addington concluded that there would be a labor-capital imbalance in the postattack economy. However, he argued that the prospects for recovery are favorable because labor could be applied to capital more intensively in the postattack economy.

Goen et al. examined various facets of economic recovery under two attack scenarios devised for use in the NESS studies--a counterforce strike, SRI A, and a countervalue strike, SRI B. Aspects of the postattack economy under examination were population, manaufacturing capacity, industrial and public management, agriculture/food processing, homeless survivors, and the availability of labor for manufacturing. Although the authors concluded that the output required for producing intermediate goods did not exceed available capacity under both attack scenarios, the demand for food products would exceed undamaged capacity by 40 percent in the SRI B attack scenario. Under both attack scenarios, petroleum refining capacity would be more than adequate to service postattack demands. However, the authors concluded that only seven additional weapons would be needed to reduce petroleum capacity below the level required for recovery. Other sectors especially vulnerable to imbalancing attacks were printing and publishing (one additional weapon) and instruments (three). Moreover, after examining surviving labor force and manufacturing capacity, the authors concluded that imbalances

in the supply of labor could reduce manufacturing output by approximately 20 percent.

Laurino and Dresch examined the Soviet threat of the 1970s, the constraints placed on that threat, the ability of the United States to take counteraction, and prospects for economic recovery. Defining four levels of economic viability--adequate, imbalanced, austere, and moribund--the authors concluded that, based on the military constraints that the Soviets faced in the early and mid-1970s, they could reduce the United States to the imbalanced level. Reduction to the austere level would require changes in Soviet objectives. An imbalanced level means that the economic system cannot function at the required level even though surviving capacity is adequate in most sectors. The austere level means that economic capacity can only sustain the surviving population.

2.3. STUDIES OF REGIONAL/LOCAL ECONOMIES

Table 2.4 provides a list of studies of regional/local economies in the aftermath of disaster using economic models. Methodologies employed in the studies included a social accounting framework (Boesman, Manly, and Ellis), an econometric approach (Ellson, Milliman, and Roberts and Munroe and Ballard), an input-output approach [Cochrane (1975)], a general equilibrium approach [Cochrane (1984)], a multi-component approach (Minor, Lambert, and Smith), and a regional systems approach (Lambert and Minor).

Table 2.4
Individual Studies of Regional/Local Economies
Economic Models

Institution	Author(s)	Date
Checchi and Co.	Boesman, Manly, and Ellis	1972
Texas Tech University	Minor, Lambert, and Smith	1972
University of Colorado	Cochrane	1975
Texas Tech University	Lambert and Minor	1975a
Pacific Gas and Electric Co.	Munroe and Ballard	1983
Colorado State University	Cochrane	1984
Multiple Universities	Ellson, Milliman, and Roberts	1984

The Boesman, Manly, and Ellis and Cochrane (1975) studies were focused on the short run potential of the economy after a disaster. The former study concluded that the gross output potential in the Louisiana-southern Mississippi region would be 57 percent of its preattack level after a 10.8-megaton attack in the area, while the results of the latter study showed that $6 billion of the predisaster level of $22 billion of value-added would be lost after an earthquake of the magnitude of the one in San Francisco in 1906. The Ellson, Milliman, and Roberts study showed the long-term economic resiliency of the Charleston, South Carolina SMSA. The authors simulated the economic performance of the region from 1981-1990 after three hypothetical earthquake scenarios and compared the results with a base case simulation over the same period. The results of the Munroe and Ballard econometric study of the potential economic loss from an earthquake in California showed the potential vulnerability of the California economy to an earthquake.

The studies at Texas Tech University were conducted primarily to develop regional modeling tools. Using a total resource system model that included manufacturing sectors and service sector inputs--oil, gas, electricity, and water--Lambert and Minor concluded that the Louisiana-southern Mississippi region is highly vulnerable to attack and recommended civil defense activities such as stockpiling and crisis relocation planning to ameliorate the vulnerability of the area.

Table 2.5 provides a list of studies of regional or local economies in the aftermath of disaster that were conducted without the use of formal economic models. The first six studies examined some aspect of recovery from a nuclear attack, while the remaining studies addressed recovery from various natural disasters.

The Clark, Truppner, and Sullivan et al. studies examined recovery prospects in the aftermath of nuclear attack in New England, Houston, and Ohio, respectively. After hypothesizing four attack scenarios, Clark concluded that, because of the dependence of the New England regional economy on the rest of the nation for many of its essential supplies, preattack stockpiling of essential commodities is important for recovery. After hypothesizing 16 different attack scenarios that included different shelter assumptions, Truppner concluded that the survival of the Houston population and the labor force across sectors is contingent on the type of shelter assumptions made. Based on his analysis of potential output in the area after the hypothesized attacks, he cautioned against using the results of aggregated national analysis to assess the economic performance of the nation because of the difficulties encountered in local areas. Sullivan addressed the vulnerability of Ohio's surviving population in the first year after attack. His primary conclusion was that a significant reduction in the number of casualties would result from a specific crisis relocation system (Program D-Prime).

The other three studies of regional economies in the aftermath of nuclear attack were damage assessments of specific geographical industrial areas. Brown studied the damage resulting from a five-megaton nuclear attack on industrial facilities within 21 miles of ground zero in the San Jose, California area. Pryor, Commerford, and Minor studied

Table 2.5
Individual Studies of Regional/Local Economies
Nonmodeling Methods

Institution	Author(s)	Date
The Rand Corporation	Clark	1956
Institute for Defense Analyses	Truppner	1965
Stanford Research Institute	Brown	1966a
Southwest Research Institute	Pryor, Commerford, & Minor	1968
Southwest Research Institute	Minor, Pryor, & Commerford	1969
System Planning Corporation	Sullivan et al.	1979
University of Texas	Brannen	1954
Institute for Defense Analyses	Kunreuther and Fiore	1966
Universities	Dacy and Kunreuther	1969
URS Research Co.	Black	1970
University of Alaska	Rogers	1970
Texas Tech University	Minor, Lambert, & Wittman	1972
University of San Francisco	Douty	1977
Universities	Friesema et al.	1979
Universities	Wright et al.	1979
Academy for Contemporary Probs.	Rubin	1981
Harbridge House, Inc.	Harbridge House	NA

NA-Not available

the effects of attack on one manufacturing complex in San Jose. The complex was a composite of five critical industries that the authors concluded were essential for recovery. In an expansion of the San Jose study, Minor, Pryor, and Commerford analyzed the effects of attack on the industrial area of Detroit.

The remainder of the studies listed in Table 2.5 were on historical natural disasters. The majority of these studies involved analysis of

short-run and/or long-term time series data--employment and retail sales, for example--to determine the effect that the disaster had on the local economies. Disasters under consideration were the 1964 earthquake in Alaska (Rogers; Dacy and Kunreuther; Kunreuther and Fiore), the 1953 tornado in Waco, Texas (Brannen), the 1906 earthquake in San Francisco (Douty), and the 1970 tornado in Lubbock, Texas (Minor, Lambert, and Wittman). Friesema et al. studied the effects of (1) the flood in Yuba City, California in December, 1955, (2) Hurricane Carla in Galveston in 1961, and (3) the tornadoes in Conway, Arkansas in 1965 and Topeka, Kansas in 1966.

The common theme that runs throughout these analyses of historical disasters is the negligible effect that the disaster had on the long-run performance of the local economy. Indeed, in many cases the long-run performance was actually enhanced by the construction of new facilities in the aftermath of the disaster. With respect to the short run, the disaster may have caused a temporary negative effect, but, even here, the influx of funds for reconstruction typically led to a marked improvement in economic performance.

Also, after a study of price movements in the aftermath of the Alaskan earthquake, Dacy and Kunreuther concluded that, because of the relative inelasticity of supply due to outside aid, prices did not increase for housing or food destroyed in the disaster. For organizational aspects of r covery, Rubin studied the local experience with six unnamed natural disasters and concluded that prior experience with natural disasters was an important factor in recovery because the relationships established with state and local officials in prior disasters facilitated management of recovery operations.

2.4. INDIVIDUAL INDUSTRY STUDIES

Table 2.6 contains a list of studies that were conducted on individual industries. The studies embraced a wide array of issues related to the vulnerability and viability of specific industries in the aftermath of a disaster. These issues include: (a) the effects of a rapid shutdown of a manufacturing complex; (b) viability analysis that incorporated both supply and demand potentials; (c) damage assessments from blast, overpressure, or fire; (d) estimated repair efforts in the aftermath of various attack scenarios; (e) attempts at modeling specific industries; (f) the degree of possible substitution between manufacturing processes; (g) the number of weapons required to imbalance or reduce an industry to nonviability; and (h) multiple industry studies under a prespecified attack scenario.

The most prominent of the latter type of study were a series of studies of transport modes undertaken at the Stanford Research Institute in the 1960s and studies of the petroleum distribution system, the natural gas system, and the electric power system as part of the Five-City Study in the 1960s. The transportation studies at the Stanford Research Institute were national in scope and were based on a predetermined set of attack scenarios.

Table 2.6
Individual Industry Studies

Industry	Institution	Author(s)	Date
Aluminum	Stanford Research Institute	Tate and Billheimer	1967
	Stanford Research Institute	Block et al.	1977
Chemical	URS Systems Corp.	Foget, Van Horn, and Staackman	1968
Construction	URS Research Co.	Van Horn	1972
Drug/Antibiotic	URS Research Co.	Staackman, Van Horn, and Foget	1970
	Research Analysis Corp.	Bull	1971
Electric Power	Department of Interior	Fernald et al.	1963a
	Stanford Research Institute	Doll, Borgeson, and Towle	1966
	URS Corp.	Van Horn, Boyd, and Foget	1967
	Department of Interior	Swart	1967
	Department of Interior	Swart	1969
	URS Research Co.	Foget and Van Horn	1969
	Stanford Research Institute	Pickering	1969
	Department of Interior	Swart	1970
	Texas Tech University	Lambert and Minor	1973a
	Department of Interior	Lambert	1976
Natural Gas	URS Corporation	Van Horn, Boyd, and Foget	1967
	Department of Interior	Richford and Davis	1967
	Department of Interior	Richford and Davis	1968
	Department of Interior	Richford and Davis	1971
	Department of Interior	Stephens and Golasinski	1974
Petroleum	Stanford Research Institute	Thayer and Shaner	1960
	Advance Research, Inc.	Fernald et al.	1965b
	Stanford Research Institute	McFadden and Bigelow	1966
	Checchi and Co.	Lerner, Grigsby, and Johnson	1967

Table 2.6 (Continued)

Industry	Institution	Author(s)	Date
Petroleum	Checchi and Co.	Grigsby, Manly, Boesman, and Johnson	1968
	Stanford Research Institute	Walker	1969
	Department of Interior	Stephens	1970
	Checchi and Co.	Boesman, Grigsby, and Manly	1970
	Checchi and Co.	Manly, Lerner, and Grigsby	1970
	Stanford Research Institute	Goen, Bothun, and Walker	1970
	Department of Interior	Stephens	1973
	General Accounting Office	Staff	1979
	Center for Planning and Research	Miller and Stratton	1980
Process Control	URS Research Co.	Van Horn and Crain	1975
Rubber	Science Applications, Inc.	Block et al.	1979
Steel	Advance Research, Inc.	Fernald et al.	1963b
	Stanford Research Institute	McFadden and Bigelow	1966
Transportation	Stanford Research Institute	Dixon, Haney, and Jones	1960
	Stanford Research Institute	Jones	1961
	Stanford Research Institute	Bigelow and Dixon	1963
	Stanford Research Institute	Andrews and Dixon	1964
	Stanford Research Institute	Crain	1965
	Stanford Research Institute	Ross	1967
	Stanford Research Institute	Dixon and Tebben	1967
	Stanford Research Institute	Hall	1967
	Stanford Research Institute	Hall	1968
	Stanford Research Institute	Hamberg	1969
	Stanford Research Institute	Hamberg and Hall	1970
	Stanford Research Institute	Hamberg	1971
	University of New Orleans	Brite and Segal	1976
	Jack Faucett Associates	Jack Faucett	1976a
	Jack Faucett Associates	Jack Faucett	1976b

One of the most significant results of the industry studies was the increasing reliance of individual industries on electronic control processes and their vulnerability to attack. In a 1975 study of both instrumentation supply and demand in the aftermath of attack, Van Horn and Crain expressed concern at the trend toward increasing use of electronic instrumentation as opposed to pneumatic instrumentation in industry as a result of rapid changes in technology. The latter form is much less vulnerable to nuclear attack in both production and use. Indeed, the authors pointed out that the most significant inputs into the production of electronic instrumentation devices--resistors and transistors, for example--are themselves geographically concentrated and highly vulnerable to nuclear attack. The results of the Van Horn and Crain study are even more ominous in light of the fact that many of the other studies listed in Table 2.6 concluded that one of the most vulnerable aspects of the functioning of the industry is the control system used in the production process.

McFadden and Bigelow examined the vulnerability of specific industries to rapid shutdown of operations. They concluded that the most vulnerable industries are petroleum refining and petrochemicals, blast furnaces and coke ovens in the steel industry, refining and smelting in the aluminum industry, and the explosives industry.

For the energy industries, the studies have generally shown that petroleum and electric power are relatively more vulnerable to nuclear attack than the natural gas industry. The transmission and distribution of electric power is particulary vulnerable at very low overpressure levels. Petroleum refining is also vulnerable because of its geographical concentration in the Southwest. The transportation of both crude oil and refined products through pipelines is especially susceptible to the effects of disasters because of both a large concentration of throughput in relatively few lines and a pipeline system's reliance on automated control processes.

3. PHYSICAL INFRASTRUCTURE: STUDIES OF THE NATIONAL ECONOMY

3.1. STUDIES USING ECONOMIC MODELS

The purpose of this section is to present the methodology and results of research conducted on the national economy in the aftermath of a generalized disaster. All of the studies reviewed in this section were undertaken using a formal model of the economy. The approach used in the presentation will be to (a) discuss the specific postdisaster issues under consideration in the study, (b) outline the modeling methodology employed to address those issues, and (c) summarize the results. The studies will be discussed sequentially, using the list presented in Table 2.1 of the preceding chapter.

The majority of studies contained in this overview were conducted in the 1960s and early 1970s. Clearly, both the economic structure of the economy and the nature of the nuclear threat have undergone dramatic change since the majority of the studies were undertaken. The purpose here is not to conjecture on the applicability of the results of those studies to the present time, but rather to delineate modeling approaches that have been used to address aspects of the economic recovery problem. Moreover, the purpose here is not to discuss all of the economic models in existence that could potentially be used to simulate economic recovery from a generalized disaster. Rather, the models incorporated in this section either have been used to simulate the recovery potential of the economy or were developed for that expressed purpose.

3.1.1. The Rand Corporation

One of the earliest modeling studies assessing the potential of the U.S. economy to recover from nuclear attack was undertaken by Paul Clark as part of a larger study of nonmilitary defense issues at the Rand Corporation [see Kahn et al. (1958)].* Clark estimated the production potential of the U.S. economy both one year and ten years following a 1500-megaton attack on the 50 largest metropolitan areas of the United States. The 50 areas, comprising one-third of the population and more than one-half of the manufacturing capacity at the time of the study, were assumed totally destroyed. The methodology employed by Clark was the use of a highly aggregated, nine-sector input-output model of the economy.**

---

*The total study was undertaken under the coordination and direction of Herman Kahn to study the potential effectiveness of non-military defense measures. Besides the economic analysis by Clark, the study encompassed foreign policy implications, various types of conventional and nonconventional fallout shelters, social problems, and tactical evacuation.

**The input-output analysis was based on a 1952 table showing the relationship between capital and gross output, linked by nine producing sectors.

By assuming that output in each sector was proportional to surviving postattack capacity (ranging from 30 to 60 percent of preattack output across sectors), Clark found that gross output in the economy would be 56 percent of preattack output after the first year following the hypothesized attack. On a per-capita basis, that level of gross output would be the same as that of 1929 or 1940. A bottleneck in the economy was the capability to produce new durable goods (metals, building materials, and machinery). Clark estimated that producing new industrial machinery at 25 percent of the preattack level would necessitate both stopping production of new consumer durables and reducing military production to a maintenance level.

Over the ten-year period, two investment scenarios were simulated under the assumption that growth in output in each of the aggregated sectors was directly proportional to the growth rate of capital in those sectors. It was also assumed that the growth rate c apital in the individual sectors of the economy was constrained by output in the durable goods and construction sectors. Under the first investment scenario, the rate of investment was assumed constant over the ten-year period and, as new capital was made available, it was assumed to be used in the production of consumer goods. Under the second investment scenario, consumption was assumed constant for the first five years following the attack and then allowed to increase in the latter five years as accumulated capital was used in the production of consumer goods. In the first scenario, gross output was estimated to be 89 percent of its preattack level after the ten-year period. The corresponding percentage in the second scenario was estimated to be 128 percent.

The results of the study led the authors to advance three preattack nonmilitary defense recommendations:

> First, stockpile construction materials for patching up partially damaged capital during the reorganization phase . . . Second, preserve normal inventories of metals, building materials, and machinery . . . Third, shelter complete plants in the durable goods sector of the economy, or possibly standby components of plants. (Kahn et al., 1958, pp. 28-29).

Clark's 1958 study was subsequently expanded at the Rand Corporation in collaboration with Donald Bear [Bear and Clark (1960)]. The primary purpose of Bear and Clark's work was to determine potential disequilibria of demand and supply (bottlenecks) in various sectors of the postattack economy after a hypothesized attack on the largest 80 U.S. cities, ranked in terms of manufacturing value added. The attack was assumed to destroy the total productive capacity of the 80 cities--56 percent of preattack capacity. Under the scenario, 60 percent of the preattack population survived. The analysis was intended (a) to isolate sectors that could prove to be a significant problem in the postattack recovery effort and, hence, (b) to provide guidance in establishing priorities for emergency operations in the recovery effort.

The authors employed a 44-sector, input-output model based on production coefficients for 1947, but updated to 1956 for the study. The

manufacturing segment of the economy, the focal point of their analysis, was disaggregated into 23 sectors.

A number of limiting assumptions were invoked in the study to determine final demand. The assumptions included: (1) the level of aggregate output in the postattack economy would be 50 percent of the preattack level; (2) disposable income would be 65 percent of the level experienced before the attack, with demand for consumer goods based on income elasticities determined from the experience of the 1930s; (3) final demand for government durable goods would be 20 percent of the preattack level; and (4) other government expenditures would be 75 percent of their preattack level.

The authors found that 13 of the 23 manufacturing sectors would experience excess demand in the postattack economy. Using an importance ratio calculated as the quotient of postattack demand to supply, the simulation results showed that instruments would experience the greatest excess demand (a 1.93 ratio of demand to supply), while textiles would experience the largest excess supply (0.5 importance ratio). Other manufacturing sectors experiencing excess demand included printing (1.58 importance ratio), nonelectric machinery (1.56), fabricated metal products (1.54), electric machinery (1.47), motor vehicles (1.46), nonferrous metals (1.36), ferrous metals (1.33), other transport equipment (1.25), miscellaneous manufactured products (1.18), apparel (1.06), food (1.04), and rubber (1.03). Other sectors experiencing excess supply were stone, clay, and glass (0.97), petroleum (0.96), chemicals (0.96), furniture (0.90), paper (0.78), lumber (0.73), tobacco (0.67), leather (0.66), and radio/television equipment (0.66). Recognizing that eight of the first nine manufacturing sectors experiencing excess demand were related to metal-working durable goods industries, the authors concluded that

> . . . the metal-working durable-goods industries deserve particular attention in devising civil defense policies to accelerate postwar economic recuperation. (Bear and Clark, 1960, p. 22).

In a later study at the Rand Corporation, Benton Massell and Charles Wolf (1962) used three measures derived from the economic development literature to examine the correspondence between the Bear-Clark results on industrial priorities in recovery from nuclear war and priorities for development of industrial sectors in a developing economy. The three development measures used by the authors included (1) an interdependence index developed by A.O. Hirschman,* (2) relative growth

---

*The interdependence index measures both backward and forward linkages for an industry. Backward linkages measure the inducement provided by the specific industry to other industries to produce inputs for it, while forward linkage measures the impetus provided by the specific industry to other industries to use its output. The former is estimated by calculating the ratio of purchased inputs to the total value of production in the sector, while the latter is estimated as the ratio of intermediate demand to total demand.

coefficients developed by H.B. Chenery,* and (3) proportionate expansion of physical output in individual sectors as targeted by India from the start of India's Second Five-Year Plan (April, 1956) to the end of its Third Five Year Plan (March, 1966). Using the Spearman rank correlation coefficient as a measure of the degree of association, they examined correlations between the Bear-Clark results and the three development measures to determine similarities and/or differences between establishing industrial sector priorities for recovery from nuclear attack and attaining higher levels of aggregate growth in the developing world.

The Spearman rank correlation coefficients for the (1) interdependence indices, (2) Chenery growth coefficients, and (3) establishment of priorities in individual sectoral growth as embodied in India's five year plans with the Bear-Clark results were -0.31, 0.44, and 0.47, respectively. The coefficients indicate an inconsistent set of results across measures of industrial priority. The results led the authors to conclude:

> The authors are inclined to accept the results as evidence, on balance, of a weak but positive correlation between priorities in (developing nations and recovery from nuclear attack). (Massell and Wolf, 1962, p. 21).

In another study at the Rand Corporation, Sidney Winter (1963) developed a highly aggregated conceptual model of the U.S. economy to determine the conditions under which economic recovery could occur--or economic collapse could result--in the aftermath of a nuclear attack. Winter defined economic viability in the following manner:

> An economy is viable if it is functioning, and capable of producing, without external aid, an output sufficiently large and appropriate in composition to: (a) provide its workers and their families with a level of consumption high enough to maintain their productivity and to give them the incentive to continue to contribute their services to the economy in a socially productive way; (b) meet any fixed claims on its output that may exist; (c) maintain the stock of real capital (including inventories) required to accomplish (a) and (b). (Winter, 1963, p. 17).

The fixed claims referred to in (b) could include expenditures for national defense, welfare requirements for the disabled, or any other type of expenditure deemed appropriate as a matter of national policy.

Concisely, Winter summarized the recovery problem as follows:

> In aggregative terms, the process of achieving viability can be viewed as a race between the reconstruction of the capital

*The Chenery growth coefficient--or elasticity--measures the ratio of the percentage change in per-capita value-added for each industrial sector to the percentage change in national income.

stock (and thus the recovery of output) and the depletion of the inventories from which essential needs are being met in the meantime. (Winter, 1963, p. vi).

In Winter's simple conceptual model used to illustrate conditions under which the economy will stagnate, collapse, or recover, surviving labor (L) and capital (K) are assumed homogeneous, with the ratio of the latter to the former (K/L) defining the productivity of labor. Output of the economy is used to (1) meet the subsistence needs of the labor force (c units per worker per time period); (2) provide the fixed claims (R) determined by national policy; and (3) replenish the capital stock (d). Any output greater than these commitments is assumed to be invested to augment the surviving postattack capital stock.

To demonstrate the recovery potential of the economy, Winter argued that there is some hypothetical level of capital stock (K^*)--given a surviving labor force level and a fixed government commitment--that is necessary to provide output that will satisfy subsistence living, the fixed commitment, and replenishment of the capital stock. Without an inventory of food, K^* is the solution to the following equation:

$$Lf(K/L) = cL + dK + R ,$$

where $f(K/L)$ = the productivity of labor,

$f'(K/L) > 0$, and

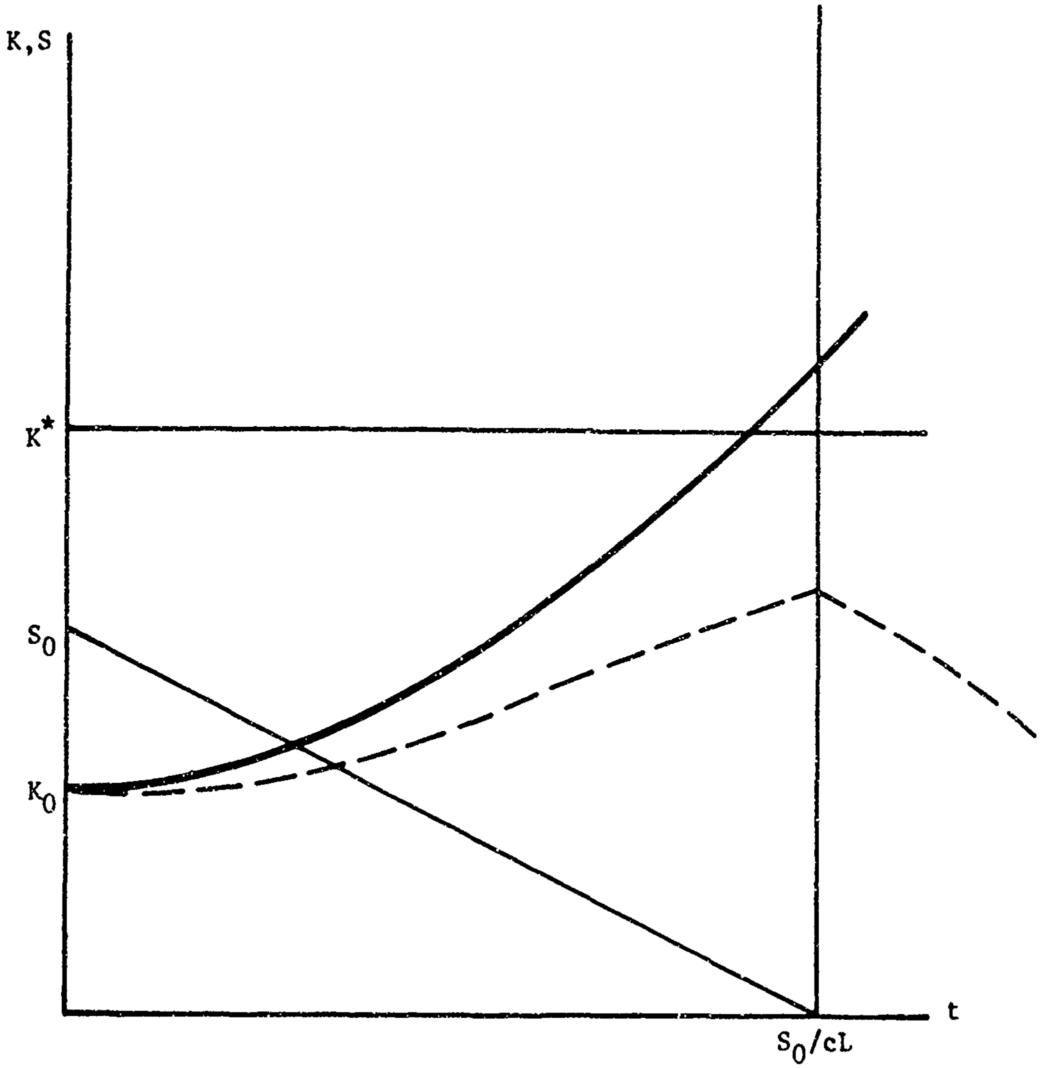
$f''(K/L) < 0$.

If the surviving capital stock (K_0) is below the hypothetical level (K^*) without an inventory of food, the economy is nonviable. Similarly, without an inventory of food, the economy will stagnate (recover) if the surviving capital equals (exceeds) the hypothetical level needed to meet the subsistence level of labor, the fixed government commitment, and replenishment of capital stock. On the other hand, given an initial stockpile of surviving food, the economy can recover with the surviving capital stock less than the hypothetical level if the food stockpiles are sufficiently large to enable the combination of labor and capital to replenish the capital stock to at least the hypothetical level before the food stockpiles are depleted. Hence, the characterization of postattack recovery by Winter is a "race" between reconstruction of the capital stock and the depletion of food inventories.

The "race" is characterized diagramatically in Figure 3.1 where S_0 is the surviving inventory of food, t is time, and all of the other variables are defined above. The broken curve in Figure 3.1 depicts a case in which the economy would collapse because food supplies are depleted before restoration of the capital stock to K^*. The solid line represents a case where the economy is viable because the capital stock is sufficient to meet all requirements before time t_v when the inventories of food are depleted.

Winter used this rather simple characterization of the postattack economy to delineate the major features of the technological feasibility

Figure 3.1
Conditions for Economic Recovery



SOURCE: Winter (1963), Figure 1, p.22.

of recovery. He recognized, however, that there are other factors which could impede economic performance and must be considered in determining recovery prospects:

> An attempt to apply the aggregative model to determine the feasibility of reorganization under various circumstances would be likely to produce overoptimistic results. The composition of the aggregates in an actual postattack situation would not be ideally suited to the needs of the reorganizing economy. (Winter, 1963, p. 28).

Other considerations that may play a significant role in postattack recovery include the disproportionate destruction of some assets (petro-

leum refining, for example); an inappropriate composition of the capital stock and surviving labor force; the geographical distribution of surviving assets; and significant changes in the composition of demand.

3.1.2. Engineering Strategic Studies Group*

J. Wright and B. Smith (1965) studied the effectiveness of a nuclear attack on the U.S. economy as a whole and in individual geographical regions. They forecasted a data base including population and industrial capacity for the 132 largest standard metropolitan statistical areas, encompassing 272 counties. At the time of writing, these areas accounted for 58 percent of the population and 83 percent of the industrial capacity of the continental United States. Economic activity was divided into 78 sectors. Sectoral input-output coefficients were derived from the Department of Commerce's 1958 interindustry study. The input-output system was solved on the basis of maximizing gross output in the postattack economy.

One of the distinguishing features of Wright and Smith's work is that they provided a range of results by incorporating three different measures of destruction in their analysis: (1) raw destruction of capacity and fatalities, (2) maximum degradation, and (3) minimum degradation. Raw destruction of economic resources was calculated using the Office of Civil Defense's DASH damage assessment system. Maximum degradation of capacity was estimated using the inflexible input-output coefficients. Minimum degradation was calculated under the assumption that not all of the inputs used in production preattack would be necessary in the postattack period. The elimination of specific inputs for certain sectors under the minimum degradation scenario was estimated by the authors. The primary purpose of using three different destruction measures was to illuminate differences in simulating recovery potential of the economy when fixed input-output coefficients are used as the basis of analysis and when these assumptions are relaxed.

The authors simulated the system under two different hypothesized attack scenarios--combination counterforce/countervalue 6,920-megaton and 10,600-megaton attacks. Under both attack scenarios, effective capacity was found to be zero, using the assumption of rigid input-output coefficients (maximum degradation). In other words, the economy would cease to function. This was true even though, under both hypothesized attack scenarios, a significant portion of raw capacity survived (82 percent in the smaller attack case and 68 percent in the larger). In the minimum degradation scenario, 78 percent of the surviving industrial capacity would be effective in the smaller attack case. The corresponding percentage for the larger attack case was 63 percent.

---

*The disc[illegible] [illegible]n Wright and Smith's study presented here is based on an overview provid[illegible] [illegible] Robert Ayres (1966c) of the Hudson Institute.

3.1.3. Institute for Defense Analyses

The Institute for Defense Analyses was involved in several modeling studies of the postattack economy. In one of the earlier studies, Henry Peskin (1965) developed a model to examine the effectiveness of appropriating expenditures for protecting industrial capacity from nuclear attack. Although the conceptual specification of a model cast in an input-output framework to evaluate budget appropriations for industrial protection was delineated, the reported simulation results did not include that specification. Other model specifications were used for the simulations.

The structure of the modeling system employed in the analysis was a 77-sector, input-output model reflecting 1958 interindustry relationships. One of the sectors was labor and the other 76 were producing sectors. Formally, total output of sector i is represented as follows in the system:

$$\sum^{j} a_{ij}X_j + F_i = X_i \ ,$$

where a_{ij} = amount of i used to produce one unit of j,

X_j = output of sector j,

F_i = final demand of sector i, and

X_i = total output of sector i.

In the simulations reported in the pilot study, Peskin solved the system on the basis of three different solution criteria: (1) unconstrained final demand [gross national product (GNP)] maximization; (2) GNP maximization constrained to be in the same proportion as preattack base-year GNP; and (3) GNP maximization with a minimal requirements vector for postattack consumer needs. Also, each of the three scenarios was simulated under the assumption of both normal labor utilization and maximum labor utilization. The latter assumption was incorporated in the simulations by using extra labor shifts to increase output from existing capacity in individual sectors. Formally, the linear program took the following form with the three different solution criteria or objective functions:

Maximize (1) ΣF_i (base-year prices)

(2) $\Sigma \alpha_i F_i$ (base-year final demand composition)

(3) $\Sigma F_i^* + zZ$ (minimum requirements vector)

Subject to $X_i \leq X_i^*$,

where α_i = proportion of total final demand accounted for by i,

$\Sigma \alpha_i = 1$,

X_i^* = postattack capacity in sector i,

F_i^* = portion of final demand determined endogenously,

z = weight for Z, and

Z = percentage of minimum final demand satisfied.

The first objective function represents simple maximization of final demand or gross output. The second objective function constrains the vector of final demands--and, therefore, the composition of gross output--to be in the same proportion as that which existed in 1958--the base year of the simulation. The third objective function divides final demand into two components--an exogenous level of minimum final demand for each sector and a portion determined endogenously in the system. Under this formulation, final demand for any individual sector i is characterized as follows:

$$F_i = Z\bar{F}_i + F_i^*,$$

where $Z \leq 1$, and

$\bar{F}$ = minimum final demand,

and gross national product is computed as follows:

$$GNP = \Sigma F_i^* + \Sigma \bar{F}_i \ .$$

An attack scenario was hypothesized, and the capacity available after the attack was computed from a damage assessment system. The hypothetical attack resulted in destruction of a large part of physical capacity measured in terms of sectoral output. For example, aircraft and parts were reduced to 7.8 percent of preattack 1958 output, while the output of petroleum products was reduced to 20.2 percent of its preattack level. However, because of assumed movement to shelter, 66 percent of the preattack population survived the attack. Six indices were used to measure performance in each sector under each of the six simulations. They included surviving capacity, excess capacity, capacity shadow price, stock shadow price, final demand, and output.

At least two important conclusions resulted from the simulations. First, the selection of a solution criterion significantly affects the simulation results. For example, assuming normal labor utilization, per-capita GNP was $753.60 (in 1958 dollars) under the unconstrained GNP maximization scenario, and it was $348.30 and $123.40, respectively, under the proportional base year and minimum final demand constraint scenarios. Second, the results of the simulations underscored the effectiveness of increasing output through more intensive use of surviving physical facilities. For each of the three solution criteria simulated, per-capita GNP is significantly larger with more intensive use of physical facilities. In the unrestricted GNP maximization and minimum final demand cases, for example, per-capita GNP more than doubled under the assumption of maximum labor utilization in comparison with the assump-

tion of normal labor utilization. Under the proportional base year case, it is a little less than twice as large.

Another interesting result of the simulations is the number of bottlenecks which arise. In the scenario which generates the largest per-capita GNP (unrestricted GNP maximization with maximum labor utilization), one-half of the producing sectors experienced a deficiency in capacity which limited further growth in the economy. In the other two scenarios, only one sector is deficient in capacity in each of the four simulations. Paint products, petroleum products, and cans, barrels, drums, and pails are among the limiting sectors in those simulations.

Although Peskin did not incorporate the industrial protection budget expenditure portion of the model in the simulations, he concluded that

> . . . any plans to budget funds for the protection of population must be preceded by a detailed and definitive study of the protection of industrial resources. (Peskin, 1965, p. viii).

The features of the modeling system used by Peskin for which no simulations were reported included five protective measures: (1) augmenting capacity or stocks in normal locations without hardening; (2) augmenting and hardening capacity or stocks; (3) augmenting capacity or stocks in a non-targeted locale; (4) hardening existing capacity or stocks; and (5) dispersing existing capacity or stocks to a nontargeted locale. The five protective measures were incorporated in an input-output framework as follows:

$$-\sum_{k} C_i^k + a_{ij} X_j + F_i = X_i ,$$

$$\sum_{k} D_i^k + X_i \le \bar{X}_i ,$$

$$-\sum_{k} E_v^k + \sum_{j} b_{vj} X_j \le \bar{Y}_v , \quad v = 1, \ldots m ,$$

$$\sum_{i}\sum_{k} c_i^k C_i^k + \sum_{i}\sum_{k} d_i^k D_i^k + \sum_{v}\sum_{k} e_v^k E_v^k \le \bar{B} ,$$

where C_i^k = amount of additional output attributable to stock augmentation in sector i for activity k,

D_i^k = amount of additional capacity attributable to capacity augmentation in sector i for activity k,

E_v^k amount of additional capital stock v attributable to activity k,

c_i^k = unit cost of implementing C in sector i,

d_i^k = unit cost of implementing D in sector i,

e_i^k = unit cost of implementing E in sector i,

b_{vj} = type v capital required per unit output of sector j,

$\bar{Y}_v$ = upper limit of postattack capital stock v,

$\bar{B}$ = civil defense budget allocation,

and all other variables are defined above.

The first terms in the first three relationships are "relief" variables in the sense that they allow increased output, capacity, and capital, respectively, as a direct result of civil defense-related industrial protection. Excluding the first term in the first two relationships, the system has the same structure as the input-output model used for the reported simulations. The fourth relationship is a civil defense budget constraint for the five industrial protection measures incorporated in the model.

As noted above, no simulations were reported for the industrial protection specification of the model due, in large measure, to problems in obtaining cost estimates for the various civil defense activities. Peskin observed:

> In practice, the development of the foregoing cost coefficients is a difficult and time consuming process. Not only are pre-attack protective measures difficult to cost, but determining the additional post-attack capacity which these measures bring about requires the application of cumbersome damage assessment models. (Peskin, 1965, p. 44-45).

Peskin also considered the specification of two other objective functions. The first is an attempt to simulate output based on a post-attack price system. That is, final demand for the output of each sector i is weighted by a factor w in an attempt to derive a market clearing system of prices for all sectors:

Maximize $\Sigma w_i F_i$.

Recognizing that determining a market clearing system of weights would be difficult a priori, Peskin suggested an iterative approach in which weights could be set arbitrarily at first and then adjusted after examining model simulations:

> If for example, there were thought to be too much clothing relative to food, the model could be re-solved with a lower weight on clothing and a higher weight on food. (Peskin, 1965, p. 35).

The second objective function is an attempt to approximate a demand curve for the final demand of each of the producing sectors. Formally, the objective function is specified as follows:

$$\text{Maximize } \sum^{i}\left[w_i^1F_i^1 + w_i^2F_i^2 + \ldots + w_i^kF_i^k\right],$$

$$\text{where } w_i^1 > w_i^2 > \ldots > w_i^k \text{ , and}$$

$$F_i^1 \leq \bar{F}_i^1,\ F_i^2 \leq \bar{F}_i^2,\ \ldots\ F_i^{k-1} \leq \bar{F}_i^{k-1} .$$

In an extension of Peskin's work, Bickley, Crane, and Pearsall (1968) estimated the recovery potential of the U.S. economy following two hypothesized attacks in June of 1975. One of the attacks (Attack A) was a counterforce attack in which military facilities were targeted and losses of population and industrial capacity were simple by-products of the attack. Under this scenario, 50 million people and 13 to 17 percent of the capital stock were destroyed. The other attack (Attack B) was a combination counterforce/countervalue strike in which both military and civilian facilities were targeted. Losses from this attack scenario were 90 million people and 34 to 41 percent of the capital stock. Although estimates of the surviving population were available for both attack scenarios, the authors simulated postattack economic performance under a number of alternate assumptions about the number of survivors. For Attack A, survivors ranged from 135 to 225 million people in increments of 10 million people, while the corresponding range for Attack B was 105 to 225 million survivors in increments of 10 million people. The estimates of surviving resources were based on studies conducted by the National Resource Analysis Center and the Office of Civil Defense.

The methodology employed by the authors to examine recovery potential was use of a static input-output model cast in a linear programming framework. The criterion for solution of the system was maximization of value added constrained on (1) the lower end by minimum final deliveries of essential survival supplies that were based on estimates of minimum per-capita survival requirements and (2) the upper end by maximum final deliveries that were based on an estimate of per-capita consumption in a 1975 preattack economy. It was further assumed that all output would be derived from current production (that is, no stockpiles or inventories were included) and that labor is homogeneous, perfectly mobile, and constrained not to exceed a fixed percentage of the surviving population.

Formally, the interindustry relationships of the economy were represented as follows:

$$\sum^{j} a_{ij}Y_j + X_i = Y_i \text{ ,}$$

where a_{ij} = input-output coefficient, amount of sector i's output used to produce one unit of j,

Y_i = total output of sector i,

Y_j = total output of sector j, and

X_i = final demand of secor i.

The input-output relationships expressed above were cast in a linear programming framework to produce the following postattack recovery problem:

$$\text{Maximize} \quad \sum^{i} X_i = V$$

$$\text{Subject to} \quad X_i \geq X_i(\min),$$

$$X_i \leq X_i(\max),$$

$$Y_i \leq \bar{Y}_i, \text{ and}$$

$$\sum^{j} b_j Y_j \leq M,$$

where V = value added minus imports = gross national product,

$\bar{Y}$ = maximum gross output of sector i,

b_j = labor used in the production of one unit of j, and

M = total postattack labor force.

The classification of industries for the study was based on the industrial interrelationships published by the U.S. Department of Commerce for 1958. Since the study was based on two attacks that were assumed to occur in 1975, estimates of the 1975 interindustry structure were required. The input-output coefficients were extrapolated to 1975 from 1970 estimates provided by the Bureau of Labor Statistics. The basis for the projection to 1975 was rates of change in the coefficients from 1958 to 1970. Minimum final deliveries for the 1975 postattack period were estimated from a combination of sources that dealt with survival needs. Maximum final deliveries were based on an extrapolation of actual per-capita final deliveries to 1975 provided by the Bureau of Labor Statistics for 1962 and 1970. Postattack industrial capacity for the individual sectors was derived by multiplying estimated preattack gross output in 1975 with both the percentage of capacity destroyed and the ratio of emergency usage to normal usage.

The simulation results suggested that prospects for postattack economic recovery are favorable. The authors concluded in part:

> This study of two sample attacks points out that the basic physical components of the economy--labor and capital goods--survive in such proportions as to ensure a reasonably high standard of living. If the chaos envisioned after a nuclear attack can be overcome, and a reorganization achieved to properly utilize the surviving resources, then the survivors of an attack in 1975 may be able to attain a standard of living comparing favorably with that of the late nineteen fifties. (Bickley, Crane, and Pearsall, 1968, p. 259).

On the potential disproportionate destruction of population and economic resources, the authors further concluded:

> If people and resources survive together in nearly equal proportions then, on a per capita basis, the economy has the potential of being as viable as before an attack. However, if resources survive in greater proportions than the population available, labor will restrict total output. On the other hand, if fewer resources survive in proportion to the population, intensive use of the available productive facilities--working additional shifts or other means of more fully utilizing capacities--a relatively high standard of per capita value added may be achieved. (Bickley, Crane, and Pearsall, 1968, p. 259).

In an extension of the 1967 Bickley, Crane, and Pearsall study, Edward Pearsall (1968) simulated the performance of the economy to ascertain the feasibility of attaining a 1958 standard of living in the aftermath of a number of different types of attacks on specific U.S. industrial sectors. The was different from the 1968 Bickley, Crane, and Pearsall work because it considered attacks explicitly designed to destroy industrial capacity rather than militiary targets or population.

The approach employed by Pearsall was to extrapolate population and industrial capacity by standard industrial classification (SIC) sector for 228 standard metropolitan statistical areas (SMSAs) to the year 1975. For each SIC category, the SMSAs were ranked in descending order based on the percentage of total capacity in 1975. Various types of attacks intended to destroy a certain fraction of industrial output were assumed for 52 individual manufacturing sectors and ports of entry. It was also assumed that if an SMSA were targeted, it was totally destroyed. That is, the targeted sector and all other industrial capacity and population in the SMSA were assumed destroyed. The economic analysis was undertaken using a static, input-output model. The estimated 1975 coefficients are the same as those used in the 1968 study by Bickley, Crane, and Pearsall (1968). Final demands for the system were estimated on the basis of (a) attaining a 1958 per-capita standard of living for final end-use goods and (b) producing potentially important goods required in the postattack period. An example of one such good is medicine.

The results of the simulations suggested that it is possible for an aggressor nation to conduct an "efficient attack"--that is, one in which the attack creates a shortage of the targeted industry's postattack capacity, leading to a failure to attain a 1958 standard of living. Attacks on 10 of the 53 sectors could be devised to reduce postattack capacity in those sectors to a level that will impede attainment of a level of output consistent with a 1958 standard of living. The basis for this conclusion was calculation of the ratio between output needed to produce a 1958 standard of living and emergency capacity, where emergency capacity is defined in a manner similar to the maximum labor utilization scenario used in the 1968 Bickley-Crane-Pearsall study. Included among the sectors susceptible to an efficient attack--ranked in order of severity--are aircraft and parts, ordnance and accessories, im-

ported products, petroleum refining, optical and photo equipment, paints and allied products, tobacco manufactures, metal containers, primary iron and steel, and professional and scientific instruments.

Although the simulation results suggested that a number of sectors of the economy are vulnerable to attacks that could impede recovery, Pearsall concluded that attacks designed for industrial destruction are not as troublesome as attacks designed to destroy population:

> Although it is certainly possible to devise a nuclear attack to induce severe scarcities of one or another industry's capacity, no attack on physical capital stocks can indirectly cause casualties or threaten the nation's economic power to the extent of an attack of comparable magnitude on the nation's population. Selective capital scarcities may be overcome rather easily in a modern economy by resorting to alternative sources of supply, by making substitutions among products and processes, by capital transfers, by massive infusions of investment capital, and by labor intensive operations of surviving facilities. (Pearsall, 1968, pp. 38-40).

Moreover, Pearsall concluded that light and moderate attacks may prove more troublesome for economic recovery than heavier attacks:

> . . . light and moderate attacks, i.e., attacks that leave more than half of the nation's population alive, may create greater problems of postattack resource balance than heavy attacks. It is very difficult to devise a heavy attack that discriminates sufficiently between industrial targets and people to create serious capacity scarcities. (Pearsall, 1968, p. 3).

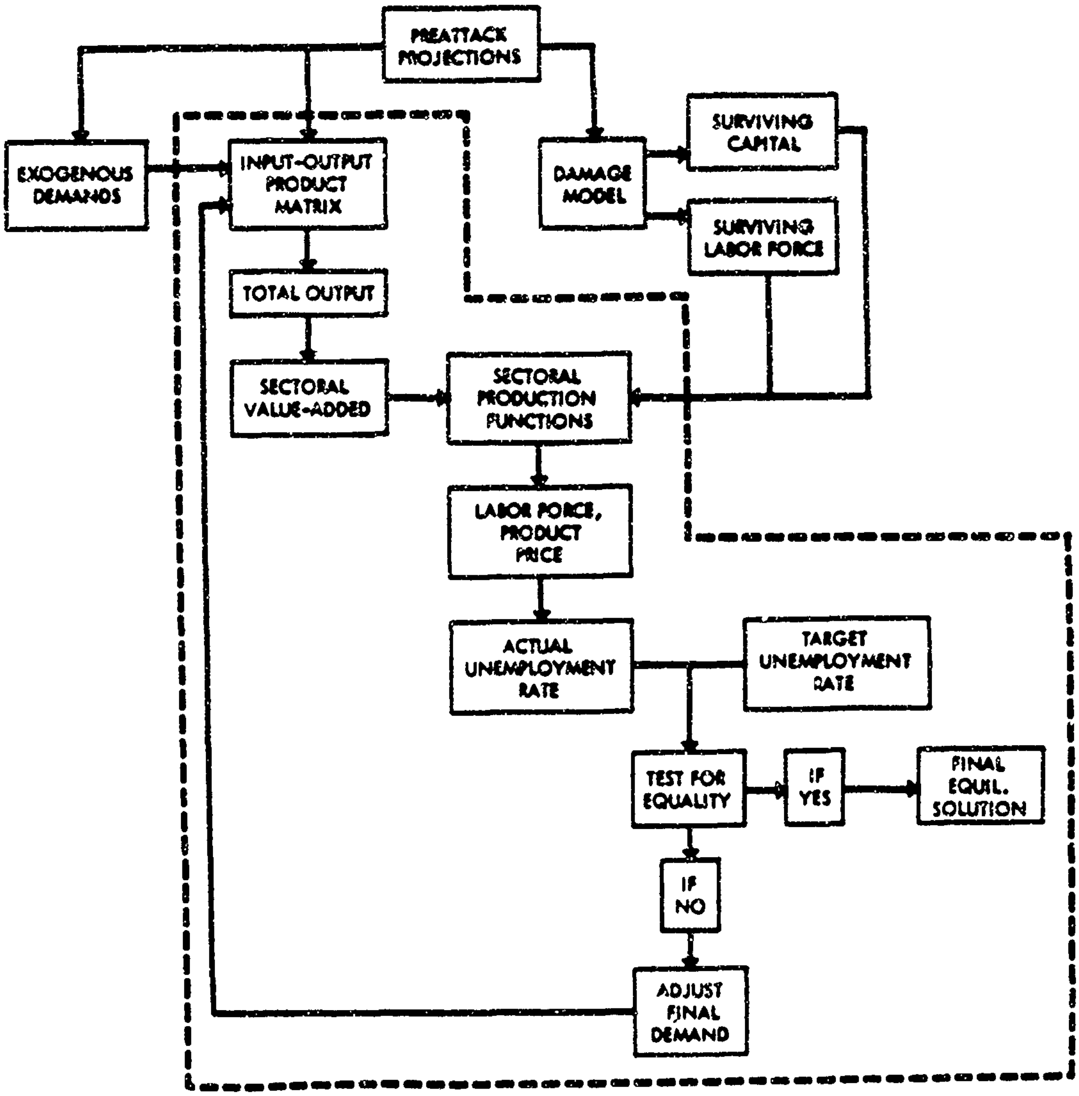
Elliot Wetzler (1970) described the specification of the Institute for Defense Analyses Economic Model developed for simulating economic performance in the recovery phase of the postattack economy. Although an 82-sector input-output model constituted the basis of the system, a number of extensions of static input-output models were incorporated. For example, constant elasticity of substitution (CES) production functions were included for each of the sectors.* Additionally, the restrictive assumption of labor homogeneity usually invoked in models of this type was relaxed by specifying different labor productivities for individual sectors. Finally, although final demand is initially pre-

---

*The estimated coefficients for the CES production functions were developed by Bruce T. Grimm (1969) in an earlier Institute for Defense Analyses study. Grimm estimated CES production function coefficients for 52 input-output sectors. Since the model developed by Wetzler contains 82-sectors, Wetzler assumed a constant relationship between labor and value added in the remaining sectors. Although Grimm explored other specifications for the production relationships (Leontief and Cobb-Douglas production functions), he concluded that the CES representation provides ". . . Much greater sensitivity to the limits of productive capacity in manufacturing industries. . ."

specified for solution of the system, the actual simulated level of final demand is determined through an iterative process in which the exogenously specified final demand vector is adjusted to attain an exogenously specified target unemployment rate. A schematic representation of the system is provided in Figure 3.2.

Figure 3.2
The IDA Postattack Economic Model



SOURCE: Wetzler (1970), p.8.

Use of the system requires three inputs: an estimate of final demand by sector, a matrix of input-output coefficients, and damage resulting from a hypothetical attack scenario. Value added by sector is determined using an input-output framework:

$$\sum^{j} a_{ij}X_j + Y_i = X_i \ ,$$

$$\sum^{i} V_i = \sum^{i} Y_i \ ,$$

where a_{ij} = the amount of sector i output required to produce one unit of j,

X_i = total output of sector i,

Y_i = final demand of sector i, and

V_i = value added in sector i.

Labor utilization by individual sectors is determined from a constant elasticity of substitution production function (for the 52 sectors where those functions have been estimated):

$$V/N = e^{\tau T}\left[\alpha(K^*/N)^{-\delta} + \beta(L/N)^{-\delta}\right]^{-\sigma/\delta} \ ,$$

where N = number of firms,

τ = rate of technological change,

T = time,

α = capital scale parameter,

K^* = short run fixed capital stock,

δ = capital-labor substitution coefficient,

β = labor scale parameter,

L = amount of labor, and

σ = economies of scale parameter.

Solving for L, the use of labor for sectors with CES production functions is represented as follows:

$$L = 1/\beta\left[(V/H)^{-\delta/\sigma} - \alpha K^{*-\delta}\right] \ ,$$

where $H = N^{1-\sigma}e^{\tau T}$.

For sectors where no CES production functions were provided, a constant relationship between labor and output was used:

$$L = bV .$$

A unique feature of the system is the relaxation of the assumption of labor homogeneity across sectors in the economy. Specifically, the model incorporates the following relationships:

$$V = f(K^*,L) \quad \text{where } L \le L^*,$$

$$V = f(K^*,L) - g(L-L^*) \quad \text{where } L > L^*, \text{ and}$$

$$g_i = W_i = w_i/\bar{W} \text{ for each sector } i,$$

where $L^* = L_0(S_1/S_0)$,

L_0 = amount of preattack labor used in sector i,

S_1 = postattack population,

S_0 = preattack population,

g = nonhomogeneity function,

w_i = absolute preattack sectoral wage rate,

$\bar{W}$ = average wage rate for the entire economy, and

W_i = sectoral wage rate.

For sectors where no CES production functions were specified, the relationships take the following form:

$$V = L/b \quad \text{where } L \le L^*, \text{ and}$$

$$V = L/b - g(L-L^*) \quad \text{where } L > L^*.$$

The rationale for this formulation of labor nonhomogeneity is that sectors with higher relative wage rates require a larger number of postattack workers to replace workers operating under preattack conditions.

Product prices, P, in the model are calculated as the sum of the marginal cost of labor and the marginal cost of intermediate inputs:

$$P_i = W_i(\partial L_i/\partial V_i) + \sum^{j} a_{ji}P_j ,$$

where the sectoral marginal product of labor is computed from the CES production function.

The rental rate of capital, R, is simply the marginal revenue product of capital:

$$R_i = P_i(\partial V_i/\partial K_i) \ .$$

From Figure 3.2, final demand is adjusted to attain a target unemployment rate. If the target unemployment rate is not attained, another iteration of the system is accomplished. The target unemployment rate, u, is defined as follows:

$$u = 1 - L_v/L_f \ ,$$

where L_v = labor force at the target unemployment rate, and

L_f = total labor force, which is defined as the product of the surviving population and the labor force participation rate.

The target unemployment rate and the labor force participation rate are exogenous inputs to the model. The actual unemployment rate, u_a, is defined as follows:

$$u_a = 1 - L/L_f \ ,$$

where $L = \Sigma L_i$ = actual labor employed.

The difference between the actual and targeted unemployment rates, u_v, is defined as

$$u_v = 1 - L/L_v \ ,$$

and is used to "scale" final demand in the following manner:

$$Y_{i,k+1} = Y_{i,k} u_v^{-q} \ ,$$

where $Y_{i,k}$ = final demand of sector i at iteration k, and

q = adjustment factor that promotes computational efficiency.

Besides the adjustment for the difference between actual and targeted values of the unemployment rate, the system constrains individual sectoral demand to equal or exceed a minimum--and not to exceed a maximum--level of final demand. The minimum final demand is a weighted average of the minimum per-capita population survival requirements and the per-capita recovery requirements. Maximum final demand is a function of damage to economic resources and population survival. Minimum (Y_{min}) and maximum (Y_{max}) final demand are calculated as follows:

$$Y_{min,i} = \left[hY_{1,i} + (1-h)Y_{2,i}\right]S_1 \ , \text{ and}$$

$$Y_{max} = \Omega\left[Y_0(K_1/K_0)(S_1/S_0)\right] \ ,$$

where S_1 = postattack population,

Y_1 = per-capita survival requirements,

Y_2 = per-capita recovery requirements,

h = survival/recovery weight,

Y_0 = preattack sectoral final demand,

K_1 = postattack sectoral capital stock,

K_0 = preattack sectoral capital stock,

S_0 = preattack population, and

Ω = scalar value (=2 as approximation of emergency capacity limits.

An added feature of the IDA Economic Model is related to the determination of the final demand vector [see Dolins (1970)]. As discussed above, final demand was adjusted on the basis of unemployment rates in the early version of the model. In the revised version, final demand is determined iteratively and explained by both gross output and relative prices, which are determined endogenously in the model.

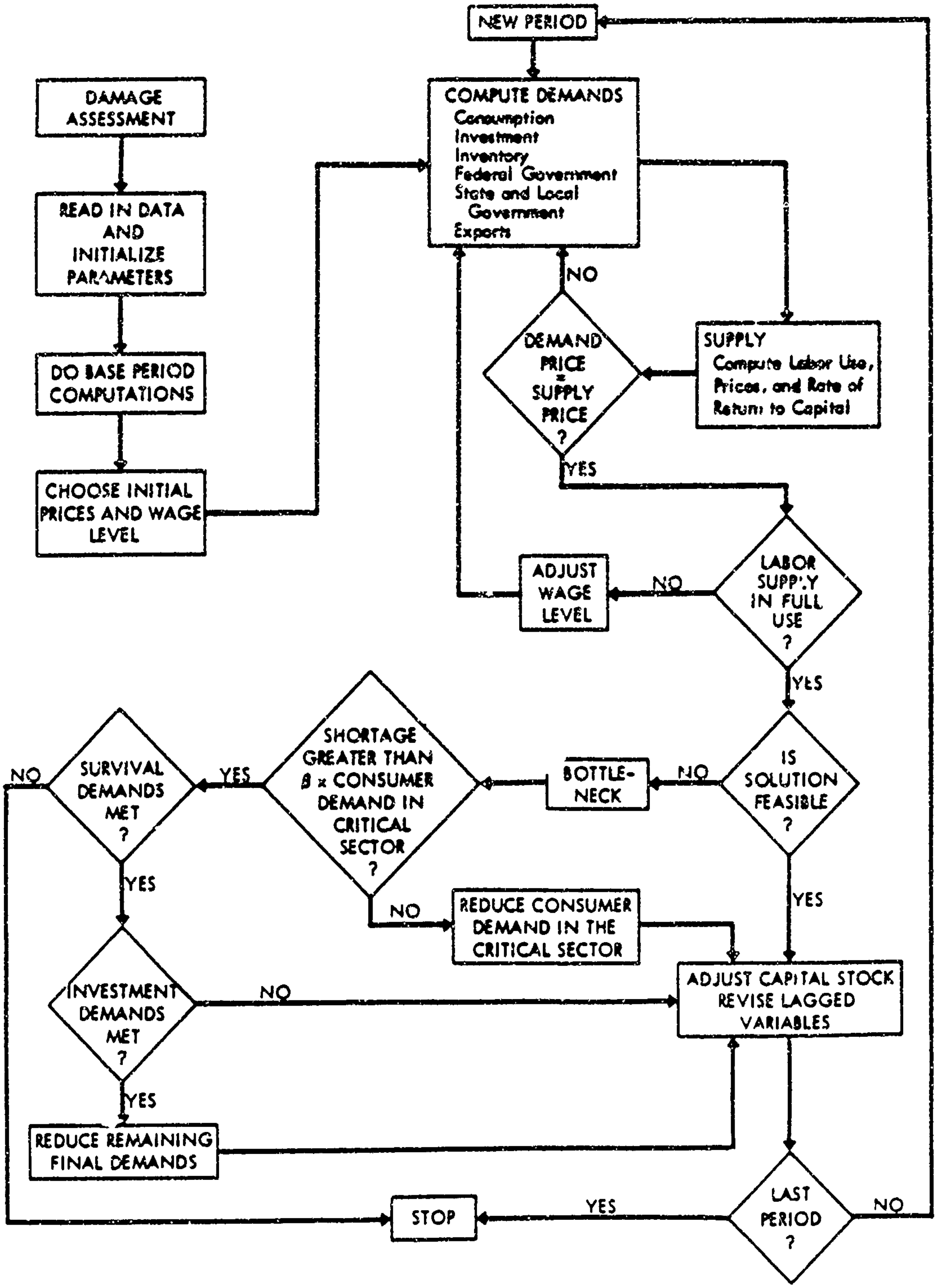
In another modeling effort at the Institute for Defense Analyses [James McGill et al. (1972)], Methodologies for Evaluating the Vulnerability of National Systems (MEVUNS) was developed. The purpose for developing the system was to evaluate the effectiveness of various defense systems and survivability requirements. The total modeling system is composed of five subsystems that characterize the national system: (1) an industrial and population data base, (2) a defense/attack generation model, (3) damage assessment models, (4) an economic recovery model, and (5) a mathematical programming model.

Figure 3.3 contains a schematic representation of the economic model embodied in MEVUNS, termed the General Economic Model (GEM). GEM contains both demand- and supply-side specifications. Solution of the system requires equilibration between the two. The wage rate is the basis on which the equilibrium solution is attained. The wage rate is adjusted to a point where a specified amount of labor is used and supply and demand are equilibrated. The supply side portion of the model combines an input-output matrix which determines inputs to production and production functions which determine the use of labor and capital with the variable inputs. The model incorporates 87 sectors derived from the Department of Commerce's interindustry study. Demand is characterized by six consuming sectors--consumption, investment, inventories, Federal government, local government, and exports. The final demands by type are then disaggregated to correspond to the 87 sectors.

The input-output specification has the standard form:

$$\sum^{j} a_{ij}X_j + Y_i = X_i \ ,$$

Figure 3.3
The General Equilibrium Model of
The MEVUNS System



SOURCE: McGill et al. (1972), Figure 11, p.87

where a_{ij} = the amount of sector i's output necessary to produce one unit in sector j,

X_i = total output of sector i,

X_j = total output of sector j, and

Y_i = final demand in sector i.

From the input-output representation, value added per unit of output is represented as follows, with p_i denoting the price of output in sector i:

$$p_i - \overset{j}{\Sigma} a_{ji} p_j \ .$$

Value added per dollar of output, u_i, is computed by dividing through by p_i:

$$u_i = 1 - \overset{j}{\Sigma} a_{ji}(p_j/p_i) \ ,$$

and total value added for sector i, V_i, is simply

$$V_i = u_i X_i \ .$$

Using sectoral value added, three production functions were used to determine the amount of labor used in each sector. The production functions take the following form:

$$V_i = H_i\left[\alpha_i L_i^{-\delta_i} + (1-\alpha_i)K_i^{-\delta_i}\right]^{-\sigma_i/\delta_i} \ ,$$

$$V_i = H_i\left[L_i^{\sigma_i\alpha_i} K_i^{\sigma_i(1-\alpha)_i}\right] \ , \text{ and}$$

$$V_i = H_i\left[\Phi_i N_i + \mu_i L_i\right]^{\sigma_i} \ ,$$

where $H_i = \Theta e^{\tau_i t} N_i^{1-\sigma_i}$,

$\delta_i = 1/\sigma - 1$,

α_i = parameter representing labor intensity in production,

L_i = amount of labor used by sector i,

K_i = amount of capital used by sector i,

σ_i = parameter determing returns to scale,

t = time from 1963 to the year of attack,

τ_i = rate of neutral technical change,

N_i = number of establishments in sector i,

Θ = efficiency parameter in 1963,

Φ_i = parameter determining relative importance of number of establishments, and

μ_i = parameter determining relative importance of labor.

The first equation represents a constant elasticity of substitution production function, while the second is of the Cobb-Douglas form. The third is a hybrid used for three sectors (imports of goods and services, business travel and entertainment, and office supplies).

From the production functions, the amount of labor used and its marginal product can be derived for each sector. The marginal product of labor is used to determine the price of output in the individual sectors:

$$p_i = \sum^{j} a_{ij}p_j + u_i w_i/(\partial V_i/\partial L_i),$$

where w_i = the wage rate in sector i.

Under this formulation, if the ratio of wages to marginal product is greater than one, prices are raised because the optimum level of output has been exceeded. The reverse is true if the ratio is less than one.

The rental rate of capital can also be derived using the marginal product of both labor and capital. Formally, the rental rate of capital for sector i, R_i, is derived as follows:

$$R_i = [w_i/(\partial V_i/\partial L_i)]\partial V_j/\partial K_i \; .$$

As discussed above, the model provides for the calculation of six components of final demand and a further disaggregation into 82 sectors. The six components of final demand include consumer goods, investment goods, inventories, Federal government expenditures, state and local government expenditures, and exports.

The demand for consumer goods was obtained by specifying econometric relationships for 82 personal consumption expenditure (PCE) categories. The explanatory variables in these equations were current and lagged prices, current and lagged income, lagged consumption, and other socioeconomic variables where appropriate. Consumption in the 82 categories was converted to the 87 producing sectors contained in the input-output portion of the model by applying coefficients developed by the Department of Commerce on the industrial composition of consumer consumption by type. The coefficents have the following form:

$$b_{ij} = c_{ij}/c_j\ , \quad i = 1, \ldots m,\ j = 1, \ldots n,$$

where $c_j = \overset{j}{\Sigma} c_{ij}$, total expenditures for PCE category j, and

c_{ij} = sector i's contribution to PCE category j.

The distribution of PCE categories to input-output sectors is accomplished as follows:

$$CONS_i = \overset{m}{\Sigma} b_{ij} c_j, \quad i = 1, \ldots n$$

Inventory demand is determined as an adjustment between desired and actual inventory levels. Formally,

$$INV_i = \Omega(Q_i^* - Q_i),$$

where INV_i = inventory accumulation in sector i,

Q_i^* = desired inventory level in sector i,

Ω = adjustment factor determining fraction of actual and desired inventory levels, and

Q_i = actual inventory level.

Desired inventory levels are determined by the following relationship:

$$Q^* = (k_i x_i / 2 r_i p_i)^{\frac{1}{2}}\ ,$$

where k_i = inventory reorder costs,

x_i = total output,

r_i = rate of return on capital, and

p_i = output price.

Expenditures by the federal government are determined by an adjustment between desired and actual per-capita expenditures:

$$FEDG_i = FEDG_{-1,i} + \Omega(FEDG_i^* - FEDG_{-1,i})\ ,$$

where $FEDG_i$ = actual per-capita expenditures,

$FEDG_{-1,i}$ = lagged per-capita expenditures,

$FEDG_i^*$ = desired expenditures on a per-capita basis, and

Ω = adjustment factor.

Total expenditures are derived from per-capita expenditures by multiplying the per-capita results by the population.

State and local government expenditures and production for export are determined by a similar adjustment process between desired and lagged expenditures.

As depicted in Figure 3.3, the solution of the model is based on two criteria: (1) equilibrating demand and supply and (2) utilizing available labor. The latter criterion is based on the assumption that a goal of postattack recovery management will be to use all productive resources to their maximum possible extent. In the event that capacity in an industry is insufficient to supply required demands, a rationing scheme is included in the specification of the model to allocate available output.

3.1.4. Stanford Research Institute

Stephen Allen (1968, 1969) of the Stanford Research Institute developed an input-output model of the U.S. economy for the U.S. Army's Advanced Ballistic Missile Defense Agency. The purpose of the model was to simulate the recovery potential of the economy after a hypothetical nuclear attack in 1975, using different attack objectives. Estimates of economic damage resulting from the hypothesized attacks were to be used in designing strategic defense systems. The total modeling system consisted of three interrelated computer programs--an attack system, a damage assessment system, and an economic model.

The economic model consisted of 79-sectors--78 producing sectors and a labor sector. The system had the following structure:

$$\sum^{j} a_{ij} Y_j + X_i = Y_i \text{ , and}$$

$$\sum^{j} b_j Y_j = L \text{ ,}$$

where a_{ij} = input-output coefficient,

Y_j = output of sector j,

X_i = final demand for i,

b_j = amount of labor to produce one unit of j, and

L = labor availability.

The objective in the linear program was to maximize total final demand or gross output (GNP), subject to minimum and maximum final demand constraints, capacity constraints, and labor constraints by sector:

$$\text{Maximize } \sum^{i} X_i$$

$$\text{Subject to } X_i \geq X_i(\text{min}) \text{ ,}$$

$$X_i \le X_i(\max) \ ,$$

$$Y_i \le Y_i^* \ , \text{ and}$$

$$L \le L^* \ ,$$

where Y^* = maximum sectoral capacity, and

L^* = maximum labor availability.

The input-output coefficients were static and estimated for the 1975 simulation year.* Minimum final per-capita demand was estimated on the basis of essential postattack recovery needs. Maximum final demand was estimated on a per-capita basis to ensure that the output of certain sectors would not result in overproduction of inessential commodities. Maximum final demand for individual sectors was estimated on the basis of expected 1975 peacetime demand. The capacity constraint was determined from the damage assessment system. Estimates of surviving capacity were upgraded to reflect emergency-to-normal usage ratios. Preattack capacities for individual sectors in 1975 were estimated from Faucett Associates data. Capacity that was simulated to be moderately destroyed in the scenarios was assumed to be useable within six months of the attack. Labor availability in the postattack period was assumed to be 30 percent of the surviving population derived from the damage assessment submodel. Labor coefficients for individual sectors were estimated for 1975, using data from the Bureau of Labor Statistics. Estimated 1975 preattack population was derived from Bureau of the Census data. Finally, it was assumed that all intermediate and final output is derived from current production. No inventories of essential goods were considered in the simulations.

In a preliminary study [Allen (1968)], two attacks were simulated--100-weapon undefended and defended attacks undertaken with the primary intent of maximizing total fatalities. The simulation results showed the importance of the use of defensive measures in planning for economic recovery. In the defended case, population survival was 18.3% greater and economic output 33.6% greater than in the undefended attack scenario. In the undefended attack scenario, three sectors--livestock and livestock products, metal containers, and communications (except radio and television)--experienced capacity restrictions; that is, total output of the sector was restricted by the amount of surviving capacity.

In a later study [Allen (1969)], comparative simulations were performed for both defended and undefended sector-oriented attacks and general attacks. For the sector-oriented attacks, a computer program was developed to devise 50-weapon and 100-weapon defended and undefended attack scenarios that would minimize the difference between surviving ca-

---

*The specification of the model was supposed to incorporate a coefficient "adjustment factor" for each individual sector, reducing coefficients in specific sectors to reflect employment of emergency technologies. However, because of the lack of a complete data set across sectors, the adjustment factors were not incorporated in the reported simulations.

pacity and minimum feasible capacity. The latter was defined as the lower bound on the amount of capacity needed for survival. Each weapon was assumed to have a three-megaton yield. Four critical sectors were chosen for analysis--machinery, petroleum refining, chemicals, and primary metals.

The simulation results for the sector-oriented attacks showed that the most critical attack would be a 50-weapon undefended attack on petroleum refineries. In this scenario, 45.3 percent of petroleum refining capacity was destroyed. Although more than 96 percent and 89 percent of the population and manufacturing value added, respectively, would survive, GNP was simulated to be the lowest under this attack scenario. Moreover, in each of the eight sector-oriented attack scenarios considered (50-weapon undefended attacks and 100-weapon defended attacks against the four critical industries), there was a capacity constraint in the petroleum refining sector. Allen explained:

> The economics of petroleum refining throughout its history has never permitted the existence of over-capacity in the industry. In fact, available data indicate that 1961 refinery capacity is very close to the minimum feasible capacity for the 1961 population. It is not surprising then that damage of almost any degree makes postattack petroleum refinery capacity binding on the economy. (Allen, 1969, p. 40).

In the generalized attack simulations, Allen considered various combinations of defended and undefended 100-weapon and 300-weapon population-oriented and economic resource-oriented attacks. The results showed that the most effective general attack was a 300-weapon undefended attack on economic resources. Under this scenario, 77.6 percent of the population would survive, but only 37.2 percent of economic resources, measured in terms of manufacturing value-added, would survive. On the other hand, the percentages of surviving population and economic resources under a 300-weapon defended attack increased to 88.2 and 73.1, respectively.

In a series of studies, Lee (1968b, 1968c, 1969, 1970) analyzed an industrial network's capability to meet the postattack demand for a specific commodity. The studies were undertaken to develop a methodolgy for industrial scheduling in the aftermath of nuclear attack. Concisely, the approach involves determining all of the processing facilities that comprise the production of a specific commodity. Each individual process within the production network is then assigned a production coefficient in a manner similar to input-output analysis. Vulnerability functions are included to provide the degree of output degradation associated with any hypothetical attack scenario. Under the approach, the postattack condition of any facility in the industrial network can be identified. Lee (1969) initially illustrated the methodology using the bread production network and later [Lee (1970)] applied it to 21 consumer commodities.

Dresch and Baum (1973) developed a combination (a) attack/damage assessment system and (b) economic recovery model to simulate recovery from nuclear attacks under a large range of postattack conditions. The

postattack conditions were functions of both the type of assumed attack and various investment strategies employed in the recovery effort. The study included the results of earlier simulations contained in Baum and Dresch (1971).

The attack/damage assessment component was specified to determine the optimal destruction of resources, given a prespecified countervalue attack objective. That is, each additional weapon was assigned to a standard metropolitan statistical area to inflict the largest destruction of resources. The outputs of the attack model--losses of physical capacity and population--were used as an input in the economic model.

The economic model consisted of seven aggregated sectors in the earlier version of the system [Baum and Dresch (1971)] and 15 sectors in the later version [Dresch and Baum (1973)]. Final demand was divided between investment expenditures (private capital formation) and consumption expenditures, which comprised all of the non-investment expenditures in the economy. Investment expenditures by sector were determined endogenously in the system, based on an allocation to individual sectors that optimized the present value of the future levels of GNP. Per-capita consumption requirements were exogenous, reflecting per-capita survival requirements over five- or nine-year planning horizons. The lead time for construction of new capital was assumed to be two years. Also, a five percent depreciation rate per annum was assumed for the capital stock.

The authors reported simulation results under varied assumptions about the level and type of attack, capital cost per dollar of output ($1.50 or $2.00), and exogenously specified level of consumption expenditures for both the 7-sector model over a five-year planning horizon and the 15-sector model over a nine-year horizon. The simulation results led Dresch and Baum to conclude:

> The results show consistent paths for economic recovery and provide plausible schedules for allocation of postattack investment among sectors. Variation in the size of the attack and postattack austerity (imposed by policy stipulated constraints on personal consumption and government expenditures) displace recovery schedules up or down without significant distortion. Recovery to preattack levels of GNP requires up to a decade after heavy attacks, but such preliminary results should be taken with caution until verified by more refined, less aggregated analyses. (Dresch and Baum, 1973, p.ii).

3.1.5. Arms Control and Disarmament Agency

Peter Strell (1968) developed a highly aggregated, six-sector input-output model of both the U.S. and Soviet economies for the Arms Control and Disarmament Agency as part of a larger study entitled "Development and Improvements of Methodology for Strategic Analysis of Arms Control and Disarmament Measures." The purpose of the model was to determine the impact of a nuclear strike on the welfare of the nation.

The six sectors incorporated in the model of the U.S. economy were aggregated from an 81-sector input-output representation of the economy provided by Leontief. The sectors included basic nonmetals, finished nonmetals, basic metals, finished metals, services, and energy. For each of the individual sectors, a Cobb-Douglas production function was specified, relating value added in the sector to capital and labor inputs. A similar model was developed to characterize the Soviet economy. The most important inputs for the models were the simulation results provided from the Strategic International Relations Nuclear Exchange Model (SIRNEM), a model that estimates the effects of nuclear exchanges between the United States and Soviet Union.

Formally, production relationships in the six sectors took the following form:

$$V = gL^sK^{1-s} ,$$

where V = value added,

g = efficiency parameter,

L = labor,

K = capital, and

s = labor share parameter.

The ratio of postattack (starred variables) to preattack levels of value added, capital, and labor formed the basis of the study:

$$V^* = (L^*/L)^s(K^*/K)^{1-s}V .$$

The values for sectoral value added in the postattack economy were used in an input-output framework to determine total final output. The input-output system took the standard form:

$$\sum^{j} a_{ij}X_j + F_i = X_i ,$$

where a_{ij} = amount of sector i's output needed to produce one unit of j,

X_i = total output of sector i, and

F_i = final demand in secor i.

Through matrix manipulation, the vector of final outpuc by sector was expressed as a function of the input-output coefficients and value-added:

$$F^* = EV^* .$$

For the simulations, a bilateral countervalue attack scenario was devised in which both the United States and Soviet Union delivered 1,000

one-megaton warheads. The simulation results for the U.S. economy showed that 64.3 percent of the U.S. population would survive with a GNP potential of 55.6 percent of the preattack level in the first year after the exchange. In this scenario, the results showed per-capita GNP at 86.3 percent of its preattack level.* However, the authors acknowledged the drawbacks of using a one-period, one-region, highly aggregated model to simulate potential postattack economic performance.

3.1.6. Research Analysis Corporation

Bernard Sobin (1968b) developed an economic model that was intended to simulate basic survival requirements of the postattack economy. While the model could be used more generally with minor modification, its primary purpose was to simulate the ability of surviving productive capacity to support human survivors in the aftermath of a hypothetical attack. Because it was a "survival model," no attempt was made to incorporate military production, investment activities, or private consumption beyond the amount needed for basic survival of the population.

The model was a linear program of the following form:

$$\text{Maximize} \quad \overset{j}{\Sigma} c_j X_j \ ,$$

$$\text{Subject to} \quad \overset{j}{\Sigma} a_{ij} X_j = b_i \ ,$$

where i = a constraint,

j = an activity,

X_j = level of the jth activity,

a_{ij} = amount of ith constraint for each unit of X_j ,

b_i = amount of ith constraint, and

c_j = prespecified contribution to the objective function per unit of activity j.

In the specification of the model, there were 82 constraints and 149 activities. The activities included supported population, three classes of production variables required for production support, and the government. Included among the constraints was a labor sector. Figure 3.4 provides a general scheme of the modeling system.

The source of information for nonagricultural sectors was the Department of Commerce's study of 1958 interindustry relationships. The

---

*The corresponding results for the Soviet Union were a 77.7 percent population survival level and 72.8 percent GNP potential (93.7 percent of its per-capita preattack level).

Figure 3.4
General Scheme of a Survival Requirements Model

Types of balance	Activities						Constant terms[a]
	Persons supported	Production			Government operations		
		Crops	Livestock products	Industrial inputs to agriculture			
Human nutrients							
Lower limits	+	−	−			$\le$	0
Upper limits	+	−	−			$\ge$	0
Livestock nutrients							
Lower limits		−	+			$\le$	0
Upper limits		−	+			$\ge$	0
Land classes							
Upper limits		+				$\le$	Postattack availability[b]
Stipulations		+				$\ge$	Postattack availability[b]
Industrial inputs to agriculture		+		−		$\le$	0
Special constraints							
Soybean-grain mix		+ −				$\le$	0
Level of government					+	=	Stipulated level of government activity
Industrial capacities	+	+	+	+	+	$\le$	Postattack availability[c]
Byproducts	+	+ −	+ −	+	+	$\le$	0
Livestock capacities			+			$\le$	Postattack availability[c]
Labor	+	+	+	+	+	$\le$	Postattack availability[c]

[a]When preceded by $\le$, $\ge$, or =, the element of the column is an upper bound, lower bound, or both, respectively, on the cumulative product. (See "Constant Terms" subsection of the section "Derivation of Model Inputs" of this paper for further interpretation of the constant-terms elements.)

[b]Same as preattack.

[c]Output of damage assessment.

SOURCE: Sobin (1968), Table 1, p.8.

agricultural sector breakdown in that study was further disaggregated to provide the largest possible detail on population-supporting sectors of the economy. For nonagricultural sectors, no production process alternatives were specified, while several alternative processes were provided for agriculture-related production.

The original version of the model was static in the sense that it did not allow for time-dependent investment. It also assumed that imports provided preattack would be available in the postattack economy. It was further assumed that any bottlenecks which may arise in the simulations cannot be obtained from foreign imports.

In a revised version of the system, Sobin (1969) developed a "partially dynamic" survival model. That is, the revised model allowed for increases in productive capacity in ten of the sectors. The ten sectors chosen for capacity augmentation were selected on the basis of (a) bottlenecks that arose in execution of the static model and (b) sectors in which the potential for bottlenecks was high. The revised model allowed for investment in capacity and disinvestment of inventories for the ten sectors in a period preceding the "steady-state period." The behavioral rule used in the dynamic case was minimization of the cost of investment.

In applications of both the static and dynamic versions of the model, Sobin simulated the survival requirements of the economy given a modified version of the SRI B attack scenario.* First, Sobin simulated the attack using the static model under the assumption that the objective was to maximize the number of persons that could be supported by surviving assets. In terms of the objective function, the only variable with a nonzero c_j was population supported. From this simulation, it was concluded that a maximum of 151 million people could be supported by surviving resources. If the survival goal was 200 million people, simulation results under the dynamic version showed that four food-processing industries required additional capacity to sustain the additional 49 million people. The four food processing industries were canned fruits and vegetables, flour milling, rice milling, and oilseed processing. Based on simulation results showing that $295 million of additional investment was needed in these four sectors to support the additional 49 million people, Sobin concluded in part:

> The small amount of investment and the small amount of labor to produce brand-new equipment and facilities sufficient to add 49 million people to the number who could be supported indefinitely from current production may seem startling, but it is consistent with the general principle that investment directed at bottleneck industries can generate tremendous increases in national product. (Sobin, 1969, p. 21).

*The SRI B attack scenario was used extensively in studies conducted at the Stanford Research Institute. It was a large-scale, countervalue nuclear attack.

3.1.7. American Technical Assistance Corporation

The Runout Production Evaluation (ROPE) model was developed to simulate the performance of the economy in the first 90 days after a hypothesized attack under assumed organizational conditions in the postattack economy. The most prominent of these conditions is that a priority system for the use of scarce resources in the industrial economy will be promulgated. The model is described by Elwyn Bull (1973a) and the results of its application to the Post-Nuclear Attack Study II was also provided by Bull (1973b).

The model included 86 sectors whose input-output coefficients were based on estimates of 1958 interindustry production relationships by the Department of Commerce. The most important feature of the model is the classification of these 86 sectors into one of two priority categories, based on the assumed importance of the sector's output in economic recovery. For each of the sectors, the distribution of output was specified to satisfy on a priority basis (1) specified final demand requirements, (2) the input requirements for first priority users, and (3) if any output of an individual supplying sector remains, the input requirements for second priority users. If there does not exist sufficient output from any sector to satisfy requirements of the first priority users, the available supply is apportioned to users on the basis of preattack share times surviving capacity. The same apportionment scheme is utilized for second priority users if available supply satisfies both final demand and the needs of first priority users, but is insufficient to satisfy the total requirements of second priority users. This allocation scheme reflects the assumption that the authorities will allocate inputs to specific sectors in this manner in the aftermath of a nuclear exchange.

In determining available supply from each of the sectors, the model includes not only output produced during the 90-day period under consideration, but also surviving inventories of inputs provided from other sectors, final goods inventories of the individual sectors, and the amount of goods in process that survived the attack. In the event that a specific sector cannot continue "normal" production due to lack of inputs but has sufficient inputs to finish its surviving goods in process, the sector switches to "runout mode" production in which new production is not initiated but goods in process are completed. It was assumed that surviving goods in process were one-half completed.

The system accounts for changes in inventories over the simulation period. Denoting normal and runout mode production by the superscripts n and r, respectively, the following relationship was included for the use of raw materials inventory produced by sector i and held by sector j from the initiation of production at t-1 to time t:

$$I_{ij}(t-1) + D_{ij} - [a_{ij}^{n}X_{j}^{n} + a_{ij}^{r}X_{j}^{r}] = I_{ij}(t) ,$$

where I_{ij} = inventories of sector i held by sector j,

D_{ij} = distribution of i to j,

a_{ij} = input-output coefficient,

X_j = output, and

t = end of 90-day period.

Similarly, for inventories of sector i's own output, the following relationship was included:

$$I_{ii}(t-1) + (X_i^n + X_i^r) - F_i - \Sigma D_{ij} = I_{ii}(t) ,$$

where F_i = final demand.

The model was solved on the basis of maximizing (a) production of output in the normal and the runout production modes and (b) purchases of inputs from the 86 sectors, subject to a capacity constraint, a purchases constraint, and a goods in process constraint:

$$\text{Maximize} \quad \Sigma X_j^n + X_j^r + \overset{ij}{\Sigma\Sigma} D_{ij} ,$$

$$\text{Subject to} \quad X_j^n + X_j^r \le X_j^* ,$$

$$D_{ij} \le a_{ij} X_j^* , \text{ and}$$

$$X_i^r \le X_i^* .$$

Using the subscripts 1 and 2 to denote sectoral priorities, the priority constraint to ensure the allocation of inputs to first priority sectors took the following form:

$$\text{If} \quad \overset{j}{\Sigma} R_{ij(1)} + F_{i(1)} \ge S_i ,$$

$$\text{Then} \quad S_{i(2)} = 0 ,$$

Where R_{ij} = requirements for output of sector i, and

S_i = supply of sector i.

As noted above, if the total amount of supply to a sector is insufficient to satisfy the needs of that sector, an allocation scheme apportions the available supply. The same apportionment scheme is used for first and second priority sectors. However, all of the needs of the first priority sectors are satisfied first. Formally,

$$D_{ij(1)} = b_{ij} \overset{j}{\Sigma} D_{ij(1)} ,$$

where $\sum^{j} b_{ij} = 1 - F_{i(1)}/X_{i(1)}$.

The model was used to simulate the performance of the economy in the first ninety days after the hypothesized PONAST II attack. In the attack scenario, 55.7 percent of the population and 34.4 percent of preattack industrial capacity survived. Inputs for the simulation--inventories, production, preattack capacity--were obtained from the Office of Emergency Preparedness or Research Analysis Corporation studies. The sectors listed as first priority in the simulation were transportation, communications, public utilities, medical services, automobile repair, maintenance and repair construction, government enterprises, and sectors contained in the Department of Commerce's List of Essential Survival Items. Of the 86 sectors incorporated in the study, 51 were classified as first-priority sectors.

Results of the model simulations showed that production was 35.3 percent of the preattack level for Priority 1 sectors and 25.6 percent for Priority 2 sectors. On a per-capita basis, the corresponding percentages for priority 1 and 2 users were 63 and 46 percent of preattack levels, respectively. Production in the normal mode was 92 percent of total simulated production. Of the 86 sectors, 52 functioned exclusively in the normal mode, while 34 produced at least a portion of their output in the runout mode. Based on the analysis, Bull concluded:

> The ROPE Model application to PONAST II implies that provision of survival essentials can be met for the initial 90-day period. Production of Priority 1 sectors, which by definition include the most essential needs, reached nearly two-thirds of preattack capacity--in the aggregate. It is likely that greater disaggregation would result in the achievement of higher production estimates with the same surviving resources. (Bull, 1973b, p. 18).

The ROPE model was subsequently disaggregated to 173 sectors [Bull and Adams (1975)]. Additionally, a labor constraint was included to constrain surviving capacity in the event that a surviving labor pool was not sufficient to use the capacity. The manpower constraint took the following form:

$$\sum^{j}(m_i^n X_i^n + m_i^r X_i^r) \leq M ,$$

where m_i = man-years of manpower input, and

M = man-years of available labor.

No simulations were reported with the description of the revised version of the model.

3.1.8. Federal Preparedness Agency

The Unclassified Nuclear Case Lesson Example of 1973 (UNCLEX-73) study was undertaken by the General War Preparedness Division of the Federal Preparedness Agency [Pettee (1978)]. Two hypothetical attack scenarios occurring in March of 1973 were considered in the study. Each of the scenarios involved 1200 weapons, totaling 6000 megatons of payload. One of the scenarios--designated MIKE--was primarily a counterforce attack in which two-thirds of the weapons were directed at military targets. The other scenario--designated CHARLIE--was primarily a countervalue strike in which two-thirds of the weapons were directed at civilian targets. The study addressed prospects for national survival in the aftermath of the two hypothetical attacks. Four elements of national strength were evaluated--population, government continuity, military security, and economic viability at the local and national level.

For the economic viability analysis at the national level, the adequacy of productive capacity to sustain recovery was measured in terms of both the balance of surviving resources and their sufficiency. Balance was measured in terms of percentage of sectoral capacity surviving and, for manufacturing sectors, the regional percentages surviving across the ten Federal regions. Sufficiency was measured as the ability of the economy to produce a minimum final demand vector in the survival period and for a period of one year following the survival period. The survival period was defined as a period of time in the immediate aftermath of the attack in which economic needs are met primarily out of inventories. For purposes of the study, the survival period was assumed to last six months.

The approach used to evaluate the productive capacity of the economy to meet minimum final demands at the national level was employment of the Interindustry National Feasible Economic Recovery System (INFERS), an input-output model of the U.S. economy. Input-output coefficients for 178 sectors in 1967 were used in the analysis.

Essential final demands for both the survival and first-year recovery periods were calculated on the basis of GNP expenditure categories and allocated to the various production sectors. The expenditure categories included personal consumption expenditures, fixed investment, changes in inventories, exports, Federal government defense purchases, Federal government nondefense purchases, and state and local government purchases. Under the MIKE scenario, it was assumed that investment during the survival and first-year recovery periods was devoted to reparation of facilities that were moderately damaged during the attack. A total of 26 sectors were included for investment expenditures. Exports were included in the analysis to ensure that funds were available to purchase imports. It was assumed that trade was available only with countries in the Western Hemisphere.

For the six-month survival period, output was assumed to be derived from production during the six-month period, surviving inventories, surviving stockpiles, and gross imports. Surviving inventories were estimated from data published by the Department of Commerce. Surviving stockpiles were estimated for materials in the National Strategic Stock-

pile. Imports were assumed to be available from countries in the Western Hemisphere. It was assumed that one-half of the actual 1973 imports from countries in the Western Hemisphere were available in the recovery period. For the six-month survival period, it was assumed that one-half of the amount available in the recovery period would be provided.

Under the counterforce MIKE scenario, supply available from all sources during the survival period (production, surviving inventories and stockpiles, and imports) was estimated to be a little more than $600 billion. On the other hand, final demand was estimated to be a little more than $100 billion. Since there was no excess demand in any of the sectors, the authors concluded:

> It is concluded that the stated final demand is shown clearly not to be optimum in any respect in view of the extensive unutilized capacity. However, if as postulated in its formulation, the stated final demand for the survival period is enough to sustain national survival, assurance of the potential for national survival is provided by the test. This indicates that indeed there could be enough production during the survival period to meet current requirements with the assistance of surviving inventories and imports. The unutilized output, however, will be of major importance as the beginning inventory of the final recovery year. (Pettee, 1978, p. 181).

During the first-year recovery period under the MIKE scenario, estimated total final demand was $308 billion, while estimated total supply was more than four times as much--$1404 billion. However, nine of the sectors experienced excess demand--alcoholic beverages, printing and publishing, drugs, cleaning preparations, toilet preparations, paints, secondary non-ferrous metals, metal containers, and photographic equipment and supplies. The authors argued that only drugs would be a limiting factor in recovery because final and intermediate demand in the other eight sectors could be adjusted without a detrimental impact on recovery. However, the deficiency in drug production could pose a serious threat to survival if epidemics or the spread of communicable diseases proved to be a significant factor in the survival and first-year recovery periods.

On the basis of the simulation results over the 18-month period, the authors concluded:

> The foregoing analysis of the post-attack production capacity of the Nation during the survival period and the first full year of the recovery period suggests that barring an outbreak of severe epidemics, the capacity of the economy to meet the requirements of survival is assured. Whether the economy does in fact sufficiently utilize the established potential depends on the ability of those directing the use of the resources, most particularly the government, to manage reasonably effective use of them As previously stated, the prospects for effective institutional response depend to a large extent on the capabilities and effectiveness of those individuals in the key

positions both of management and government. (Pettee, 1978, p. 186).

The same methodological approach was used for evaluating prospects for economic survival in the aftermath of the CHARLIE (countervalue) attack. During the survival period, the authors estimated that total final demand would be $67 billion, while total available supply would be $444 billion. However, in contrast to the economic performance of the economy during the survival period under the MIKE scenario, five sectors exhibited excess demand in the CHARLIE scenario (guided missiles, nonferrous forgings, transformers and electric gears, aircraft engines, and locomotives and cars) because of extensive damage in each of the sectors. The authors concluded that the sectors should not pose a problem for national survival because of feasible final demand adjustments in each of the deficient sectors:

> None of these constraints appear to be fatal to national survival through the survival period. The adequacies of the military category constraints is scenario-dependent in any case. If full-scale conflict were to continue, probably even the stated final demand requirement would be inadequate. As it is, the cutback in the rate of public service industry repair would be serious, but the amount of the reduction probably would not induce collapse (Pettee, 1978, p. 230).

For the first-year recovery period under the CHARLIE scenario, the simulation results showed that total final demand would be $212 billion and total supply would be $1045 billion. However, 16 sectors experienced excess demand. The sectors included guided missiles, printing and publishing, drugs, cleaning preparations, paints, iron and steel forgings, secondary nonferrous metals, non-ferrous forgings, engines and turbines, transformers and electric applications, telephone and telegraph applications, radio and TV equipment, aircraft engines, shipbuilding and repair, locomotives and railroad cars, and photo equipment and supplies.

The authors concluded that only six of the deficient sectors (drugs, engines and turbines, transformers and electric applications, telephone and telegraph applications, radio and TV equipment, and locomotives and rail cars) could pose a threat to economic survival, but that threat was severe:

> The economy is in no position to cope with any major communicable disease epidemic with the limitation on the availability of drugs. More pervasive and widespread, however, is the probable damage to the public service sectors of rail transportation, communication, and electric power . . . Holding the institutional fabric of the Nation together in the face of the extremely severe public service constraint will require the most heroic and persistent government effort. Extreme want and despair will threaten the stability of the government itself if these hardships are not accepted and finally surmounted. With so many respects in which the failure of national recovery is gravely threatened, it appears most unlikely that

all of the pitfalls could be avoided and the national survival sustained. (Pettee, 1978, p. 238).

3.1.9. Analytical Assessments Corporation

Gary Hill and Peter Gardiner (1979) developed a system dynamics model to assess the viability of the U.S. economy in the aftermath of nuclear attack. The focal point of the research was to determine whether economic recovery after a nuclear strike was "automatic"--given a surviving resource base--or whether management of surviving resources would be instrumental in determining postattack economic performance. The concept of viability used by the authors in their assessment was the one developed by Sidney Winter (1963)--a "race" between utilizing surviving inventories in the immediate postattack period and increasing productive capacity to enhance those inventories through postattack production.

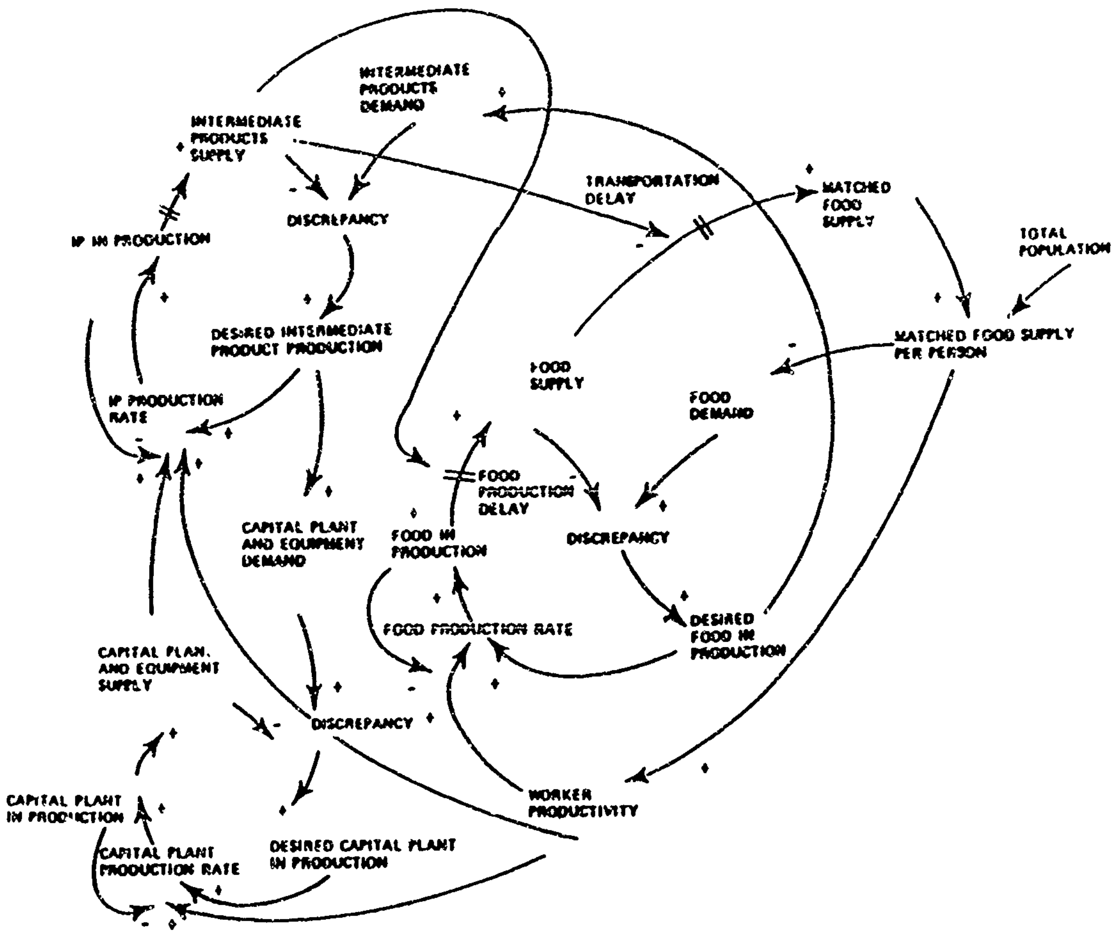
The authors selected a system dynamics approach because they believed that it is most effective in capturing the fundamental characteristics of the economy in the postattack period. The model included: (1) delays in the production system; (2) a dynamic system; (3) uncertainty; (4) flexible production coefficients; (5) a nonlinear relationship between productive inputs and outputs; (6) management options; and (7) various degrees of aggregation. Concisely, the system dynamics approach characterized the economy as a system comprised of various subsystems that are time-dependent, interrelated, and reliant to a considerable extent on behavioral characteristics as well as structural components.

Post-Attack Model No. 4 (PAM4) developed by the authors to simulate postattack viability contained four sectors: plant and equipment, intermediate products, labor, and food supplies. The food component was further divided into production, transportation, and distribution. The components were related via feedback loops that are characterized in terms of both information and material flows. Figure 3.5 provides a schematic representation of the system, highlighting the causal and feedback relationships. The (+) and (-) signs depict the direction of causality, the arrows represent the direction of causation, and the crossed lines on the arrows show delays between two components.

The reason for this specification was to develop a rather simplistic formulation of the postattack economy with little effort expended on exactly quantifying the parameters of the system. The intent was to determine whether a given model could simulate two conflicting results for postattack recovery--collapse and viability. In the words of the authors, the rationale for this is that "if viability cannot be shown to be a potential problem, there is little need to focus extensive resources on developing exact sets of numbers and policies for precise calibration of the model."

The parameters used for the simulations were related to prospective management policies that could be implemented to coordinate economic activity. Included among the parameters were the initial conditions of the economy, the effect of food shortages on labor productivity, the ef-

Figure 3.5
Postattack Model Number 4



SOURCE: Hill and Gardiner (1979), Figure 2, p. 17.

fect of communications delays, the effect of labor allocation rules, the effect of delays for locating and retraining labor, and the effect of increased expectations about food availability over time.

Perturbing various model parameters and simulating over a 24-month period led the authors to conclude:

> The evidence suggests that the issue of viability is greatly dependent on effective emergency preparedness policies and resource management actions. The simulation results from the PAM4 model clearly indicate that viability is not automatic even if adequate productive capacities survive; the same system can produce both viability and collapse depending on the choice of policies and management strategies. (Hill and Gardiner, 1979, p. 37).

3.1.10. Pugh-Roberts Associates

David Peterson et al. (1980) developed another system dynamics model of the U.S. economy. The model differed from the Hill-Gardiner effort in that it explicitly characterized the input-output structure of the economy. Moreover, because the input-output coefficients were determined endogenously in the solution of the system--from base year values--the system is dynamic in comparison with earlier fixed or static input-output models.

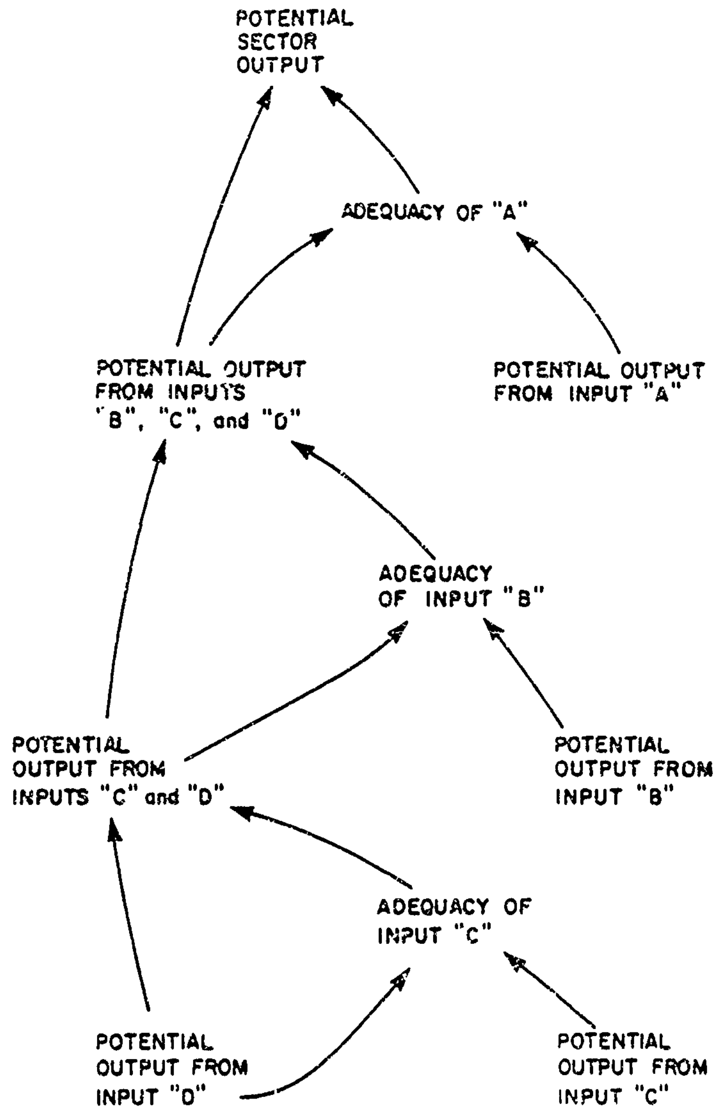
The economy contains thirteen sectors in the Pugh-Roberts dynamic system. Eleven of those sectors are considered producing sectors, while two others represent households and the government at all levels--Federal, state, and local. The thirteen sectors are further classified as production, product transfer, and consumption. The production sector includes construction, consumer goods, energy products, metals, nonmetallic durables, nonfuel consumables, agriculture, and capital goods. The transfer sectors are transportation, services, medical services, and the service portion of the government. The consuming sectors are households and the nonservice portion of government.

The relationship between the sectors is characterized using input-output coefficients. The coefficients were derived from a 1967 interindustry study of the U.S. economy. The sectoral flows in that study were aggregated to correspond to the 13 sectors included in the system. However, the coefficients can be adjusted through financial, production, and technological relationships in the model.

The financial structure includes sectoral balance sheets and income statements that form the basis for simulating debt attraction and pricing. With respect to the former, balance sheet considerations determine the amount of debt that can be obtained from capital markets. The sectoral price of output is determined by the average cost of production and a target profit margin that is adjusted on the basis of the interaction of market forces.

A "soft-minimum" production function is included for each of the producing sectors. The function is illustrated in Figure 3.6. Potential output from any producing sector reflects the "adequacy" of each of the individual inputs used in production. The adequacy of an input is a function of the ratio of the potential production from that input to other inputs. From Figure 3.6, if it is assumed that inputs A and B are in sufficient supply, sectoral output can be measured as the product of the potential output from D and the adequacy of C, where the latter is measured as the ratio of the potential output from C to the potential output from D. For an input that is not critical for production in the postattack economy, the adequacy of the function may be greater than zero (but less than one) even though none of the input is available. On the other hand, for inputs that are absolutely essential for production, nonavailability of the input implies that no production is forthcoming even if all other inputs used in production are available in sufficient quantities. In the latter case, the adequacy of that input is zero.

Figure 3.6
Soft-Minimum Production Function



SOURCE: Peterson et al. (1980), Figure 4.3-4, p. 46

Technological change was incorporated in the model by specifying the productivity of individual factors of production. Specifically, a scale of zero to three was included to represent a continuum of technology levels. Level one characterizes technology that existed in the sectors in 1965.

Sectoral investment was included through a capital budgeting process. The desired level of capital stock is contingent on obsolescence, expected demand, and expectations about the profitability of new investments. Constraints on capital investment are manifested in the sectoral financial structure in which cash flow and the ability to attract debt are modeled.

A unique attribute of the system is the treatment of the population sector. The population sector influences the postattack economy in two ways. First, it determines demand for goods and services. Second, it provides labor. With respect to labor, the system determines the labor force, divided between the employed and the unemployed portions. The number of workers who are not able to provide productive services because they are either sick or injured are also calculated. Additionally, psychological parameters are included to capture the economic effects of confidence levels, degrees of frustration, and responsiveness to the government's handling of the crisis. For example, public confidence--comprised of five factors in the model--determines the extent to which the population offers its services in labor markets, the extent of consumption (and, thus, savings), and labor productivity.

The government sector includes explicit consideration of the government's budget--both revenue sources and expenditures. Also, both by including sectoral production, transfer, and consumption and incorporating a number of policy parameters, the model can simulate the effect of government policies on economic performance. Among the possible policy choices are wage and price controls, provision of financial incentives, rationing, materials allocation, and subsidies.

The authors reported two types of simulations with the model. First, they executed a base line simulation from 1965 to 2005. The simulation results from 1965 to 1977 were compared with historical data to determine the forecasting accuracy of the model. The authors maintained that, in general, the model provides results which are "reasonably close, within the goal of ±20% of accuracy" to the historical time series.

The purpose of the second set of simulations was to examine economic recovery potential under various assumed attack effects and policy options at the disposal of the Federal government. One of the most important aspects of postattack recovery that the authors attempted to ascertain is the effect of the psychological response of the population on the recovery effort. To this end, they reported the results of three simulations of the model, comparing and contrasting psychological effects.

In the first simulation, the authors assumed that 10 percent of all economic resources were destroyed proportionally across the economy in 1981--a balanced attack. The simulation results showed a dramatic 10 percent drop in economic output in the immediate aftermath of the attack, but a return to the preattack growth rate immediately thereafter. In the second simulation, the authors assumed a 50 percent proportionate destruction of resources across the economy. The results of this simulation showed an immediate 50 percent reduction in output but, instead of recovering to preattack rates of growth in the ensuing years, the economy stagnated over the long term, operating at one-third of its postattack potential. The authors attributed the stagnation to the psychological response of the population, which was included in the simulation on the basis of the historical record of responses to disasters. To further investigate the psychological effects of attack, the authors executed the same 50 percent proportionate destruction scenario with

public confidence held at normal levels in the simulations. The results of this simulation were similar to the 10 percent destruction scenario; the immediate response was a 50 percent decline in output, but the ensuing growth rate returned to its preattack level. Based on these simulations, the authors concluded:

> The preceding three simulations suggest that the psychological response of the population determines a threshold of damage, beyond which the economy becomes as vulnerable to its own internal dynamics as it is to nuclear weapons. Because the post-attack environment is highly uncertain, and well outside the range of numerical data used to validate the model, this "threshold" level of damage is difficult to estimate with precision . . . The current assumptions in the model, derived from (qualitative data), suggest the threshold of the downward spiral lies between 25% and 50% destruction. (Peterson et al., 1980, p. 104).

To investigate the effects of government intervention in the economy, the authors simulated the second scenario discussed above--a 50 percent balanced attack with psychological effects included--but further assumed that industrial credit was enhanced by increasing the maximum debt-to-equity constraint embodied in the model. The results of the simulation showed a reversal of the stagnation in the earlier experiment, but at a lower rate of growth than the preattack level.

In another set of experiments, the authors assumed an unbalanced attack on the economy. In the scenario, 50 percent of physical resources were destroyed, but only 25 percent of the population was assumed killed and another 25 percent assumed injured. Psychological effects were held constant. The purpose of the simulations was to determine the effect of financial reform on economic recovery. In the first experiment, the destruction of assets in the attack reduced the equity portion of capital, leaving debt at the same levels. In this case, the economy grew for approximately three years after the attack, then generally declined. In the second simulation, losses reduced debt and equity proportionately because the government was assumed to engage in some type of financial intervention. In this scenario, the economy achieves a positive growth path.

Based on these and other simulations, the authors concluded:

> . . . the simulations of the model suggest that the United States economy is highly vulnerable to nuclear attack. The policies and rules of thumb by which industry, labor, and the government operate have evolved over a long period of relative economic stability. Outside the narrow range of historical conditions, the economic system exhibits many instabilities and vulnerabilities. (Peterson et al., 1980, p. 112).

Although the authors acknowledged that the results should be considered tentative, they concluded further:

> . . . the above conclusions can be shown, using the model, to arise from rather basic features of the economy. Taken together, the results emphasize the need for extensive civil defense preparations in order to create the possibility of recovery. (Peterson et al., 1980, p. 116).

The authors called for an extensive civil defense effort, consisting of intensive investment and preparation. Besides providing shelters, hardening facilities, and dispersing resources, the authors recommended stockpiling and preserving equipment and "know-how"--technological information, records, and skilled personnel. With respect to psychological aspects of recovery, the authors pointed out the importance of both not trying to reconstruct the preattack condition of the population in the postattack environment and attempting to maintain public confidence preattack by educating and developing realistic expectations of postattack life.

Peterson et al. (1981) also reported the simulation results of a four-sector natural resources model with the same characteristics as the 13-sector model discussed above. The four natural resource sectors included metallic durable materials, nonmetallic durable materials, nonfuel consumable materials, and energy products.

As in the previous study, the authors executed two types of simulations with the natural resources model. The first type was a base line simulation from 1965-2000 that was used to determine the correspondence of simulation results with historical data from 1965-1977. The results of the historical simulations showed that, for most of the important variables, the model's results were within ±10 percent.

The authors executed six hypothetical attack scenarios with no government policy changes and a number of combinations of attack scenarios with various changes in government policy. Based on the simulations, the authors concluded that

> . . . the most conspicuous, recurring impediment to recovery illuminated by the model is the post-attack cash flow crisis. In the aftermath of a nuclear attack, the natural resource sectors of the U.S. economy will have to undertake massive capital investment programs to rebuild. Clearly, the magnitude of required investment depends on the damage suffered and on the level and recovery rate of resource demands. Nevertheless, under a wide range of attack scenarios, this is the major recovery problem. (Peterson et al., 1981, p. 159).

3.1.11. Decision Science Applications

The Dynamic Economic Values (DYNEVAL) model was developed by Decision Science Applications (1983) to project the theoretical ability of an economy to recover from any number of disturbances. The disturbances include recovery from nuclear war. The model is normative in the sense that, given an economic disturbance, it projects the optimal or efficient allocation of resources to produce output, subject to maximizing a

dynamic objective function. Data requirements include information on the input-output structure of the economy.

The specification of the model included three basic sectors: production, capital investment, and consumption. The methodology employed to generate the efficient solution is optimal control. Supply and demand are equilibrated for every individual year and are in dynamic equilibrium with capital investment. Simulation results were reported for various hypothetical attacks on the Soviet Union.

3.1.12. Battelle Pacific Northwest Laboratories

The system dynamics model developed by Peterson et al. was updated and refined by Belzer and Roop (1984) of Pacific Northwest Laboratories as the Economic Recovery Dynamics Model (ERDYM). Besides incorporating 1972 base-year data, the authors built a monetary sector into the system and changed the investment sector from a capital budgeting process to a system that conforms more closely to neoclassical economic theory.

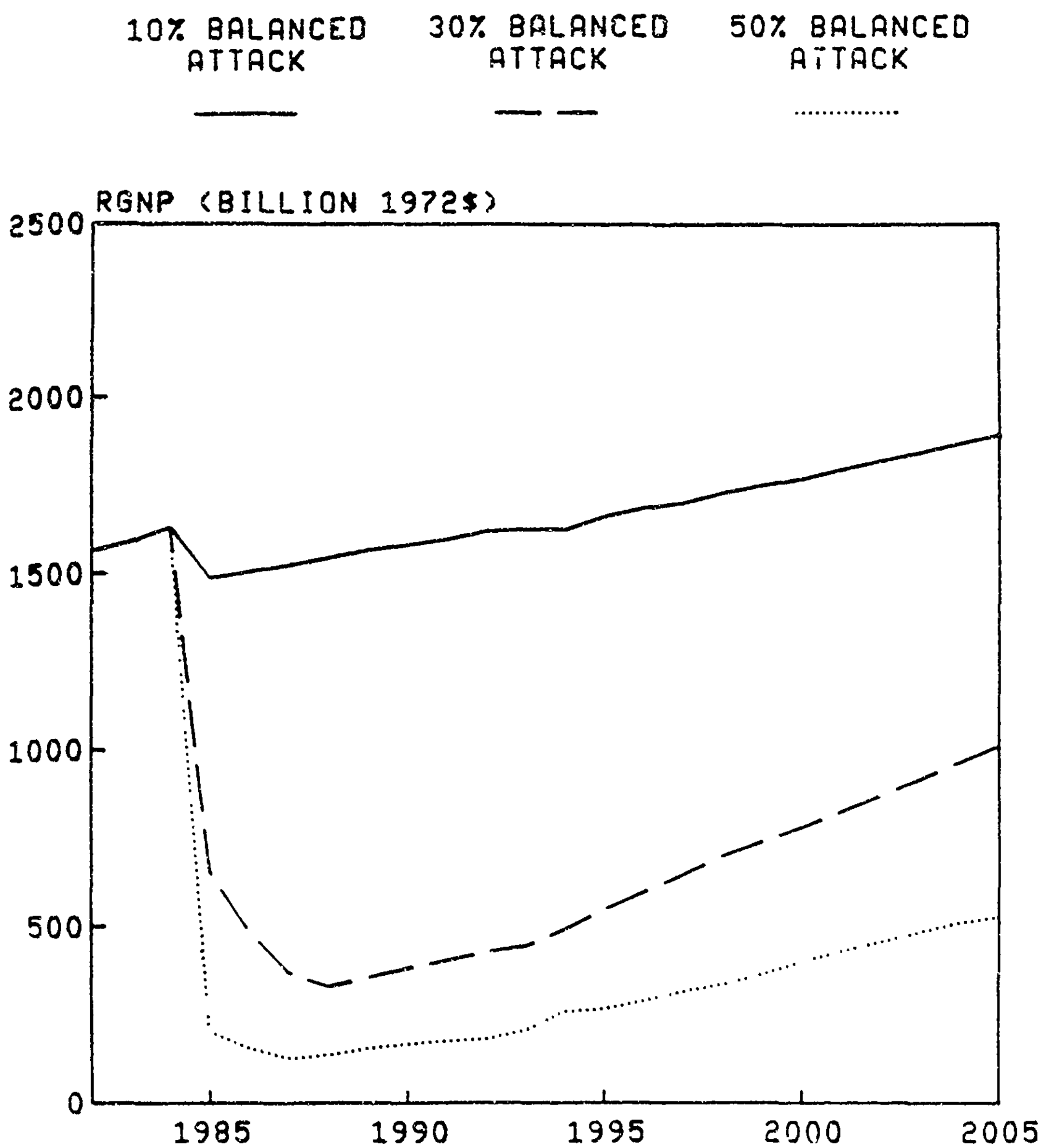
The monetary sector in ERDYM consists of a balance sheet reflecting the assets of the banking system (loans and required reserves) and the liabilities of the system, which include household and business demand deposits, the reserve base and borrowed reserves. The level of business demand deposits originates in the sectoral financial statements in which business cash requirements are determined. Household demand deposits were incorporated as a function of the interest elasticity of demand for money (-0.2 in the model) and the income elasticity of demand (assumed to be one).

The mechanism through which interest rates are endogenized in the system is the reserve base. Any activity that influences the level of the reserve base--purchases of bonds by the monetary sector, for example--has an impact on interest rates. In this case, purchases of bonds reduce the reserve base and, if remaining reserves are inadequate to satisfy the required reserve constraint in the banking system, additional reserves must be borrowed. The percentage of required reserves that must be borrowed is used as an indicator of the required change in the government interest rate. Business and savings interest rates are, in turn, a function of the government's interest rate.

Modifications to sectoral investment were made for both the availability of investment funds--or, alternatively, the willingness of financial institutions to accommodate investment demand--and the decision to invest for replacement or expansion of the capital stock. In the earlier version of the model, the willingness to lend was based largely on historical debt-to-equity ratios. This specification was modified to include a moving average of sectoral debt and the real interest rate derived from the monetary sector. Investment decisions were altered to include the rental cost of capital as the determinant of investment decisions. The rental cost of capital was determined from tax and interest rates.

The authors reported the results of a number of simulations using the model. First, they executed the system under the assumption of three balanced attack scenarios of 10 percent, 30 percent, and 50 percent destruction. A balanced attack is one in which it is assumed that equal percentages of all resources are destroyed. For these simulations, the authors also assumed that foreign trade was interrupted for the first six years following the assumed attacks in early 1984, and resumed gradually thereafter to reach normal levels a decade after the attack. The results of these three simulations are provided in Figure 3.7.

Figure 3.7
Simulated Real GNP Under Three Attack Scenarios
Economic Recovery Dynamics Model



SOURCE: Belzer and Roop (1984), Figure 6.2, p. 6.5.

The nonlinear relationship between attack levels and gross output led the authors to conclude:

> The downward spiral in these 30 and 50 percent cases can be traced to the psychological reaction of the population to the more massive levels of destruction. With tangible evidence of the horror of the attack all around them, the population loses confidence in the future. This decline of confidence is manifested in many workers leaving the labor force, and in declines in work effort by those that do remain employed. Further reduction in public confidence then occurs in response to the drop in output caused by these initial responses by workers. Thus, a downward spiral in national economic activity is generated as public confidence, worker attitudes, and losses in production all reinforce one another. (Belzer and Roop, 1984, pp. 6.3, 6.6).

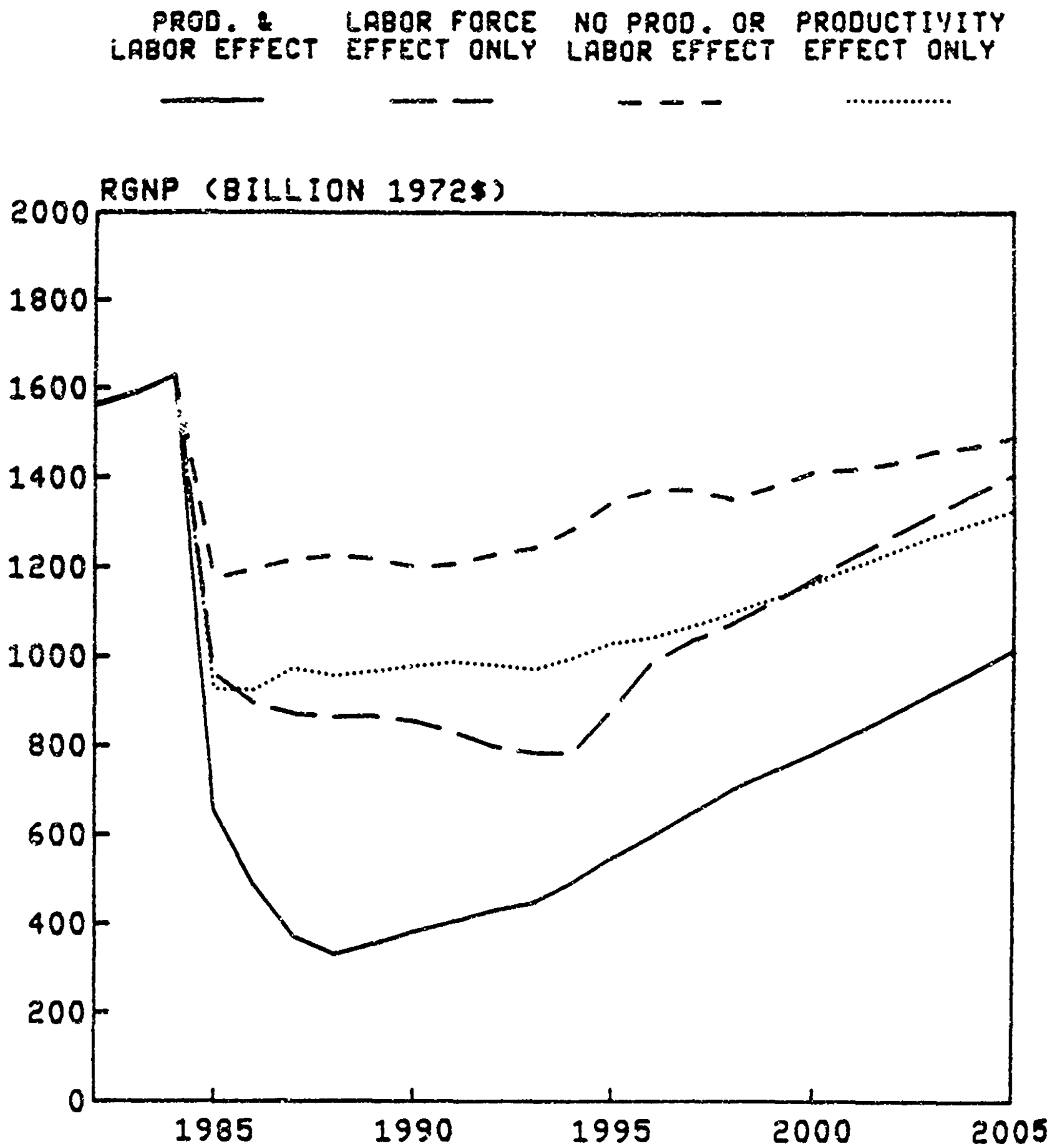
To compare the interactive effects of the psychological parameters in the model that influence productivity and labor force participation, the authors selected the 30 percent balanced attack scenario and performed three simulations: (1) psychological response affecting labor force participation only; (2) psychological response affecting productivity only; and (3) no psychological response. The results of the simulations are presented in Figure 3.8. The bottom growth path in the figure is the same as the 30 percent balanced attack in Figure 3.7. The simulation results showed the large effect that psychological factors have on economic performance when those factors are allowed to affect productivity and labor force participation.

The authors also used the model to simulate the performance of the economy under a number of different policy assumptions. In one set of simulations, the authors compared the performance of the economy under two monetary policy options. Under the first "standard" assumption, the target aggregate growth rate was 2.5 percent, the target unemployment rate was six percent, and the target inflation rate was three percent. Under the second "relaxed" case, the respective targets were 10 percent, four percent, and 20 percent. It was further assumed that the monetary policy pursued under the second simulation would last for six years from 1984--the date of the attack--to 1990 and then revert to the standard case. Figure 3.9 provides the simulated real growth of the economy under the two simulations.

Figure 3.9 shows that the real growth of the economy is higher under the relaxed monetary policy case, but, although not depicted here, at the expense of a higher price level. These results led the authors to conclude:

> These two simulations reveal that monetary policy may have the capacity to propel the economy on a higher growth path following an attack. However, this can only be accomplished by the acceptance of higher rates of inflation. This conclusion would, of course, be altered if other policies such as price-wage controls or more restrictive fiscal policy were undertaken concurrently. (Belzer and Roop, 1984, p. 6.14).

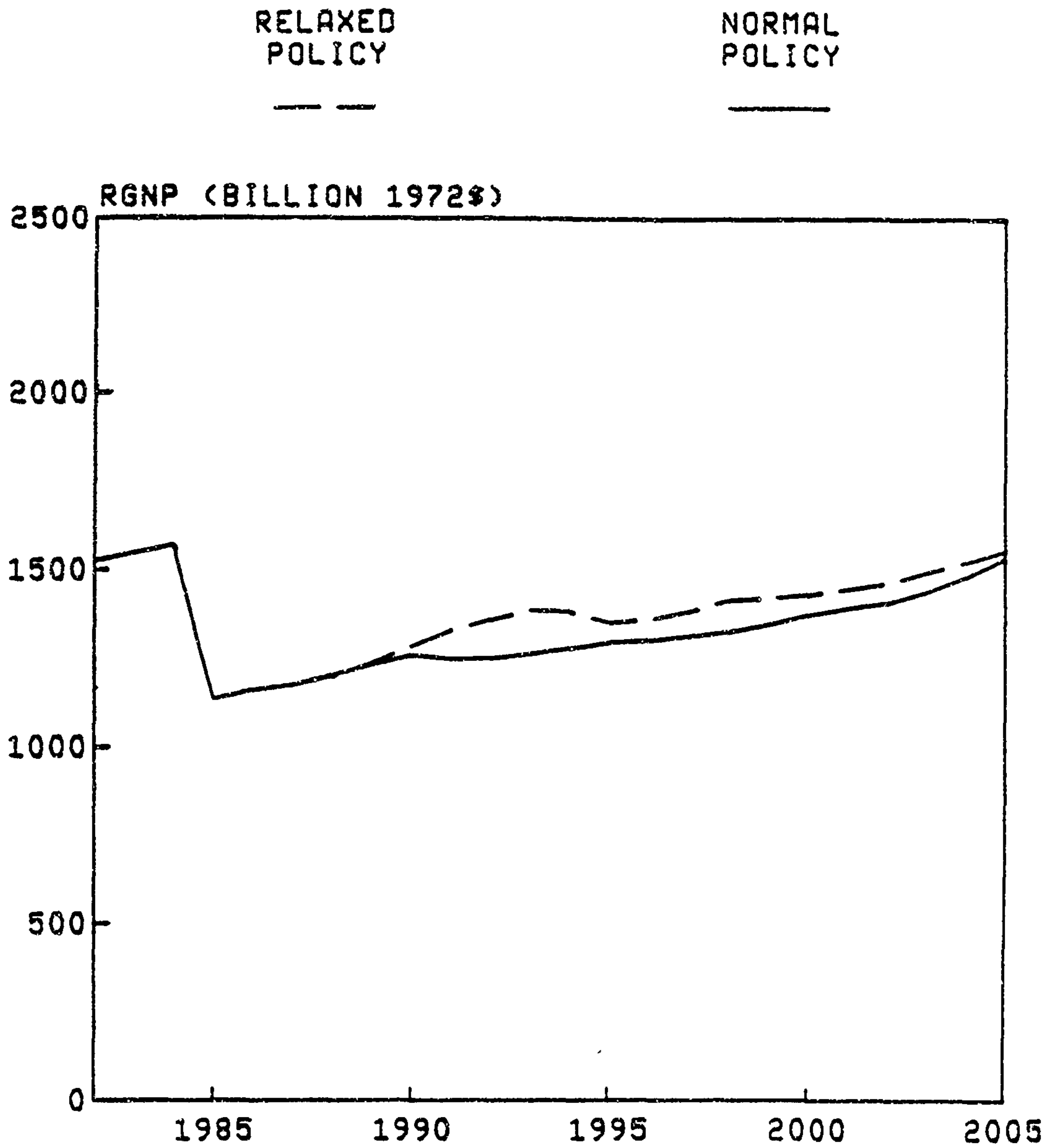
Figure 3.8
Simulated Real GNP Under Alternate Assumptions of
Psychological Effects
Economic Recovery Dynamics Model



SOURCE: Belzer and Roop (1984), Figure 6.4, p. 6.8.

The authors also reported the results of a number of simulations of economic performance in the aftermath of an unbalanced attack in which all stock variables in the model were reduced by 30 percent with the exception of the energy and transportation sectors. Stocks in these two sectors were reduced by 50 percent. After simulating the performance of the economy under alternate interest rate scenarios, personal income tax

Figure 3.9
Simulated Real GNP Under Two Monetary Policy Scenarios
Economic Recovery Dynamics Model



SOURCE: Belzer and Roop (1984), Figure 6.5, p. 6.10.

adjustments, and household motor vehicle rationing, the authors concluded:

> The message of these simulations is clear. Targeted policies directed at the shortages after an unbalanced attack can be highly effective in promoting faster recovery. Although general fiscal and monetary policy can help to shift resources toward capital investment, more direct approaches such as di-

rect rationing, may be unavoidable in the aftermath of a major attack. (Belzer and Roop, 1984, p. 6.19).

3.2. STUDIES USING NONMODELING METHODS

The purpose of this section is to describe studies of the national economy in the aftermath of a generalized disaster that were undertaken without the development of a formal model of the national economy as their primary purpose.* The eight studies reviewed in this section are economic resource assessments, emphasizing various aspects of economic viability and recovery in the aftermath of nuclear attack. Five studies [Norman Hanunian (1966), Richard Laurino (1967), Lloyd Addington (1968), and Leonard Bickley (1968, 1969)] evaluated indicators of survival. To varying degrees, these studies emphasized surviving population, economic resources, and institutions. Three studies [Richard Goen et al. (1967, 1969) and Richard Laurino and Francis Dresch (1971)] were more in depth analyses of various aspects of recovery potential. These individual studies were undertaken as part of a much larger study of recovery potential entitled the National Entity Survival Study.**

Hanunian (1966) of the Rand Corporation explored the effects of eight hypothetical attacks on 28 U.S. "populations". The eight hypothetical attacks were selected on the basis of a detailed analysis of targeting opportunities and reflect a wide range of potential attack scenarios. Hanunian selected five different targeting systems, with three of the systems having different hypothesized delivered megatonnage. The attack sizes varied from 855 megatons to 13,200 megatons. Recognizing that prior studies dealt with two indicators of survival--people and economic capacity measured by value added--he focused on 28 different "populations" that characterize an economy. Included among these characteristics were land area; population disaggregated into various categories by age, income, and location; employment by sector; value added; and various attributes of agricultural production. The damage estimates were conducted both on a regional and national basis using Quick Count, a damage assessment system developed at the Rand Corporation.

---

*During the discussion in the section, it will be evident that some of the studies relied to some extent on a formal modeling structure. However, the primary purpose of all of the studies in this section was not to develop or refine a formal economic model, but to analyze aspects of the postattack recovery problem relying, for the most part, on other analytical approaches.

**The National Entity Survival Study (NESS) consisted of a series of studies of the postattack environment conducted by the Stanford Research Institute (SRI). The purpose of the studies was to evaluate survival and recovery prospects after nuclear attack. The series was sponsored by the U.S. Army's Office of Research and Development and the Office of Civil Defense. The studies encompassed multiple aspects of the recovery problem--damage assessment, individual industry evaluations, and construction of economic models to address recovery potential.

A large part of the analysis dealt with the regional effects of these attacks on both population and economic resources. However, one of the most important results of the study was the relatively favorable prognosis for agriculture in the postattack economy. Based on his use of a Cobb-Douglas production function fitted for both farm and nonfarm output in the postattack period, Hanunian concluded in part:

> One of the more persistent results of our calculations is that agriculture generally promises to fare better, in the event of nuclear attack, than the rest of the economy. When it does fare better, the margin tends to be large. Survival rates calculated for farm workers, for example, are frequently in the vicinity of 50 percent higher than those for their urban fellows, even when differences in shelter are taken into account. (Hanunian, 1966, p. 135).

Although the results of the study showed that prospects for recovery are generally favorable, Hanunian cautioned:

> A good part . . . has been devoted to exploring viability considerations, and by and large we have found nothing to persuade us that the prognosis is negative. But we have not come to grips at all with severe organizational problems that would inevitably be present after attacks as disruptive as those which we have concerned ourselves. (Hanunian, 1966, p. 140).

Laurino (1967) of the Stanford Research Institute analyzed the effect of a nuclear attack on the national entity. Besides population and physical resources, Laurino argued that there are other "measures of value" that must be incorporated in an analysis of the vulnerability of the national entity. He evaluated the concentration of indirect indicators of national value such as population, physical resources, and some of the more important economic institutions.* Based on his assessment of the concentration of values, he concluded:

> The concentration of the economic and political institutions is substantially greater than the concentration of either the population or the physical resources of the country, and these institutions tend to be concentrated in the principal cities of the United States. (Laurino, 1967, p. 6).

The economic and political institutions considered by Laurino were Federal administration, managers in primary metals industries, prime contractors of the Federal government, the location of corporate headquarters, and employees of financial and legal institutions.

---

*In a subsequent paper, Laurino and associates at the Stanford Research Institute (SRI) [Laurino et al. (1970)] developed the NESS A value system as part of the National Entity Survival Study (NESS) at SRI. The NESS A system is a multi-element measure of value that is comprised of the weighted average of resources, population, and institutions.

Based on a hypothesized attack on both civilian and military targets, Laurino found significant imbalances in the surviving entity. Although 60 percent of the population would survive the attack, industrial capacity, public administration, and central management would experience more severe losses. Even though 60 percent--or 140 million people--would survive the attack, Laurino estimated that only 38 million would be "effective" in the six months immediately following an attack.

Addington (1968) of the Army's Office of Chief of Engineers conducted a study of the economic viability of the United States in the aftermath of a nuclear attack in 1975. The approach was simply to extrapolate population, employment, and industrial data bases on a county basis from 1960, impose various attack scenarios on the data bases, and ascertain the viability of the U.S. economy in 1975.

For employment, the study incorporated 116 skill levels forecasted from 1960 Bureau of the Census data. At the county level, the study assumed that the growth rate of a skill in any county would mirror the national growth rate for that type of employment and the rate of growth of the population locally and nationally. For the industrial data base, the author used the Department of Commerce's 86-sector characterization of the economy and allocated activity to counties in 1975 by assuming that the size of a local industry was proportionate to the size of the national industry.

Based on several different attack scenarios under different assumed civil defense postures, Addington found an imbalance between the surviving labor force and industrial capacity. However, the imbalance was based on normal utilization of labor in a peacetime economy. After reviewing the World War II experience of the United States and its Allies, Addington concluded that labor would not be a constraint in the postattack recovery effort:

> Using as a basis (the experience of Allies), which included a 56-hour week, more women in the labor force, and greater utilization of 14-to-17 year olds, we could attain about 90 percent of our preattack level of labor effort even after a very damaging attack. With this maximum utilization of labor we would have large numbers of workers in excess of those required to operate the residual industry. (Addington, 1967, p. 238).

Bickley (1968) of the Institute for Defense Analyses related the concentration of population with the concentration of 13 selected resources at the county level to determine the effects of an attack aimed primarily at population centers. The 13 resources were categorized on the basis of (a) immediate postattack survival needs--retail trade, food stores, wholesale sales of groceries, selected services, and hospital bed capacity; (b) nonagricultural resources used in recovery--manufacturing value added, large manufacturing plants, power generation, oil and gas extraction, and petroleum bulk stations and terminals; and (c) agricultural resources--value of crops, poultry, and livestock. Since 300 of the more than 3000 counties accounted for 64 percent of the popu-

lation at the time of the study, these 300 counties formed the basis of the analysis.

The results of the analysis showed that the most concentrated of the resources under examination in relation to population concentration was wholesale grocery sales and selected services. The least concentrated of the resources in population centers was the value of poultry, crops, and livestock, oil and gas extraction, and electric power stations. Perhaps the most surprising aspect of the analysis was that medical facilities were less concentrated than the population in the counties. Bickley attributed that result to the fact that veterans' hospitals and state mental hospitals were located in areas removed from large urban concentrations. Another explanation was that the data used in the analysis included stored emergency hospitals.

In a later study, Bickley (1969) quantified the geographic concentration of manufacturing industries to illuminate potential problems related to manufacturing concentration for civil defense planning. Categorizing industrial activity at the four-digit SIC level, Bickley used employment numbers at the individual plant level as a percentage of the national employment total to measure concentration.

Although he was not able to draw any specific conclusions on the pattern of manufacturing concentration, Bickley concluded that manufacturing concentration poses a significant problem for civil defense planning:

> . . . by a careful selection of a relatively small number of plants as targets, an enemy could destroy a large portion of several selected industries. That he could economically destroy practically all of many selected industries seems doubtful. Nevertheless, because of the interdependence of industries with each other a serious disturbance of the mix might be achieved which could have a far-reaching effect on the economic viability of the industrial economy as a whole. (Bickley, 1969, p. 24).

As part of the National Entity Survival Study (NESS) at the Stanford Research Institute, Goen et al. (1967) examined the extent to which important elements of the national entity would survive two hypothetical nuclear strikes in 1975 and some of the problems that would likely arise in the postattack period. The aspects of the national entity under consideration were the population, manufacturing industry, industrial and public management, and agriculture. One of the attacks (SRI A) was exclusively a counterforce attack. SRI B, the second attack under consideration, was more severe in that the assumed targets of the attack were extended to include population and resources.

The effects of the two hypothesized attacks were derived from several models and data bases that were developed in prior SRI studies. The extent of damage after the two attacks was estimated using the SRI damage assessment system developed over a period of years at SRI. The Miller fallout model was used to estimate the effects of radioactive

fallout after the two attacks. Blast effects were calculated using the Defense Intelligence Agency's vulnerability handbook.

The SRI A attack resulted in 47 million fatalities out of a forecasted population of 226 million people in 1975. The number of effective survivors (or the potential labor force) was estimated to be 66.5 million people. Surviving industrial capacity was 79 percent of preattack capacity. The industrial survival percentages ranged from 72 percent for primary metals to 56 percent for transport equipment. In the SRI B scenario, there were 89 million fatalities and only 43.5 million effective survivors. Industrial capacity was only 52 percent of the preattack level with the largest in chemicals (42 percent) and the lowest in instruments (20 percent).

The authors assessed the effects of the two attacks on central management of industry and state and Federal administration in the government. Under the SRI A attack, central management and public administration survival rates were approximately the same as that of the population. However, under the countervalue assumptions of SRI B, approximately one-half of central management and public administration were estimated to survive in comparison with 60 percent of the population.

The authors expended a significant amount of effort on issues associated with the restoration of the economy. Specifically, they examined the extent to which surviving capacity could meet the demands for intermediate goods required by that capacity, the requirements of the consuming sector, and petroleum requirements for food production, transportation, and industrial needs. They also considered the effects of radiation on agricultural production, and presented a detailed analysis of the effort required to restore manufacturing activity.

For intermediate goods production under the SRI A attack scenario, the authors found that output required for continued production did not exceed the surviving capacity in any of the sectors examined. A similar result was found for the SRI B attack. With respect to capacity available for consumption requirements, the authors found no limiting interindustry problems under SRI A, but found that the demand for the output of the food processing industry under SRI B would exceed surviving capacity by 40 percent. However, the authors concluded that repair of the more lightly damaged facilities could easily reduce that discrepancy. The authors concluded that there would be considerable excess capacity for the production of petroleum products under both attack scenarios. Under SRI A, demand would be 2.3 million barrels per day with undamaged capacity capable of producing 7 million barrels per day. Under the SRI B scenario, the level of demand would be 20 percent of surviving capacity. The authors cautioned, however, that petroleum refineries are especially vulnerable to attack because of their concentration and, therefore, attacks utilizing relatively few weapons aimed at destroying petroleum refineries could produce excess demand in the industry.

In a continuation of the 1967 study, Goen et al. (1969) defined a sequence of three phases in postattack recovery and focused attention on potential problem areas in each of the three phases. First, in the initial recovery phase (initial emergence from shelter to areas of perma-

nent relocation), the focus was on shelter availability in surrounding undamaged areas. The Detroit metropolitan area was given special consideration. In the second recovery phase, the ability of agriculture and food processing activities to support the surviving population was emphasized. In the third phase (economic recovery), the authors evaluated conditions in the damaged economy to determine if recovery could occur. The SRI B countervalue attack discussed above was the assumed attack scenario.

Based on a detailed examination of the effects of weapons on metropolitan areas, the authors found conditions favorable for relocating the homeless in the intial recovery phase. Nationally, out of 31 million homeless survivors, the authors estimated that approximately all but 5 million could be relocated in areas within 60 miles of the damaged urban area with a population-to-housing ratio of less than three relative to the preattack level. Moreover, given the same population density. all but two million of the homeless survivors could be relocated within 100 miles of the damaged urban areas. The most crowded area would be the Miami-Fort Lauderdale metropolitan area.

For the second phase of recovery dealing with food availability, the authors examined the ability of both undamaged food processing facilities in the grain and sugar industries and food inventories to sustain the surviving population. Based on analysis of undamaged capacity and the assumption that all inputs required for production were available, the authors found that the combination of sugar stocks and surviving sugar capacity for raw cane sugar, cane sugar, and beet sugar were sufficient to supply the surviving population. However, because of the relatively large survival rate in the beet sugar industry, a larger proportion of postattack requirements would necessarily come from this source. Since the processing of wheat--especially for flour--is the primary use of grain products, the authors devoted special attention to flour milling. Their analysis suggested that surviving wheat processing capacity is a bottleneck under the assumed attack scenario. The capacity of that industry can only produce 53 percent of the grain products required in an emergency diet. The authors argued that the deficiency in capacity can be reduced by repairing damaged plants, consuming wheat in some less refined form, or converting feed mills to flour production.

Based on an analysis of the surviving labor force and manufacturing capacity, the authors concluded that, in the third recovery phase,

> The surviving manufacturing plants, in general, would be faced with a labor shortage. Many of the surviving plants would lose a substantial fraction of their work forces. At the same time, many of the workers of plants that are destroyed would survive. But the work forces of destroyed plants could not be utilized immediately in the surviving plants. The integration of large numbers of new workers into the depleted work forces of the surviving plants would require time, and a major organizational effort may be required to direct the unemployed workers to the surviving plants. (Goen et al., 1969, p. 49).

The authors estimated that the constraint on labor would reduce manufacturing deliveries by approximately 20 percent.

The authors extended the analysis beyond the SRI B scenario to determine the number of additional weapons that would be required to reduce the postattack output of individual two-digit SIC sectors below the minimum level required for recovery. In these attacks designed to "imbalance" the economy, the authors found that printing and publishing (one additional weapon), instruments (five), and petroleum (seven) are the three most vulnerable. Additionally, it would take 32 additional weapons on the food processing industry to imbalance the economy. The least vulnerable of the sectors were found to be electrical machinery (175) and all other machinery (175).

In another part of NESS at the Stanford Research Institute, Laurino and Dresch (1971) evaluated the capability of the nation to survive a nuclear attack in the 1970s. Although recognizing that increases in the sophistication of targeting and nuclear arsenals had probably eroded some of the nation's survival capability, the authors nevertheless maintained that

> . . . survival prospects improve when consideration is given to realistic strategic constraints on the attacker and the capability of the United States to take counteraction. (Laurino and Dresch, 1971, p. 9).

Based on this observation, the authors examined the strategic threat of the Soviet Union in the 1970s, the ramifications of that threat for economic survival, and the potential effect of economic countermeasures to ameliorate the effects of attack. The countermeasures that were examined included expedient production measures and limitation orders.

With respect to the Soviet threat and ramifications for survival, the authors made a distinction between four different levels of viability: (1) adequate, where the level of damage does not preclude meeting a wide range of domestic and international objectives; (2) imbalanced, where the economic system cannot function at the required level even though surviving capacity in most sectors exists at an adequate level; (3) austere, where economic capacity is only sufficient to sustain the surviving population; and (4) moribund, where economic capacity cannot sustain the surviving population.

Based on detailed examination of the Soviet threat in the 1970s, the authors developed an optimal targeting system under some "fundamental policy constraints" that mitigate the potential level of the attacks. Using the targeting scheme, the authors examined the effect of various "optimal"--in the sense of their analysis of the Soviet threat--one-megaton attacks on one measure of value--manufacturing value added (MVA). The purpose of the scenario was to determine whether there are any breakpoints in the economic system, where a breakpoint is defined in a manner similar to a bottleneck--surviving capacity in a sector cannot

satisfy all of the demands for the output of that sector.* Based on their analysis, the authors concluded:

> . . . considering the threat levels and strategic constraints, attacks optimizing damage against MVA would not greatly hinder U.S. strategic objectives as represented by the OEP-IDA (demand) vector.

However, the authors argued that using MVA--or, indeed, any other single indicator such as population or GNP--as a measure of value understates the complexity of the economic system. Therefore, they used the NESS A value system to evaluate the effects of a more strategic attack, given the policy constraints imposed on the combatants. The NESS A value system is defined as the weighted average of population, resources, and economic and political institutions. Political institutions were defined as the federal public administration, while economic institutions were defined as employees in central management.

Examination of attack levels using this system of values led the authors to conclude:

> . . . it would appear that within the estimated force levels and strategic constraints for the early and mid-1970's, the Soviets could reduce the United States to the imbalanced viability level. Reduction of the United States to the austere level would also be possible, but to do so would require a major change in Soviet strategic objectives . . . Damage at these levels does not imply that the United States could not survive and recover. It would mean a change in recovery rate and in early recovery goals. (Laurino and Dresch, 1971, p. 38)

Laurino and Dresch also considered optimized--in the sense described above--one-megaton attacks against selected individual industrial sectors that may be targeted to imbalance the U.S. economy. The results of this analysis showed that there were a number of sectors that are vulnerable to imbalancing attacks. The most vulnerable sector was petroleum refining. Only 12 one-megaton optimally sited weapons could reduce that industry to breakpoint.

---

*The demand vector that was used in the analysis was developed by the Institute for Defense Analyses in concert with the Office of Emergency Preparedness.

4. PHYSICAL INFRASTRUCTURE: STUDIES OF REGIONAL/LOCAL ECONOMIES

4.1. STUDIES USING ECONOMIC MODELS

The purpose of this section is to discuss seven studies of regional/local economies in the aftermath of a disaster. The common element of each of the studies is the use of a formal economic model of the region under consideration to analyze disaster effects. Three of the studies [William Boesman, Robert Manly, and Richard Ellis (1972); Joseph Minor, Brian Lambert, and Milton Smith (1972); and Brian Lambert and Joseph Minor (1975a)] addressed regional economic recovery in the Louisiana-southern Mississippi region. The other four studies dealt with various aspects of economic recovery in the aftermath of a natural disaster. Harold Cochrane (1975) and Tapan Munroe and Kenneth Ballard (1983) simulated the economic effects of a hypothetical earthquake in California. Richard Eilson, Jerome Milliman, and R. Blaine Roberts (1984) examined the long-term economic impact of a hypothetical earthquake in the Charleston, South Carolina area. Harold Cochrane (1984) developed a general equilibrium model of a regional economy to provide a framework for examining the economic effects of natural disasters.

Boesman, Manly, and Ellis (1972) developed a modeling approach to evaluate the economic vulnerability of the national economy or any subnational economy to nuclear attack. The approach, based on what was termed the "mesoeconomic" concept, related the national system of social accounting to the profit and loss and balance sheet accounts of individual firms or sectors of the economy. The modeling approach was applied to the Louisiana-southern Mississippi region.

The income side of gross output in the social accounting system was characterized as follows:

$$Y = V_a + D + T + E \ ,$$

where Y = gross national product,

V_a = value added for factor payments for wages, salaries, rent, interest, and dividends,

D = depreciation,

T = taxes (the sum of indirect business, corporate profit, and social insurance taxes), and

E = retained earnings.

This representation was termed "mesoeconomic" because it characterizes gross output of the economy in a manner similar to the income statement of an individual firm.

The corresponding relationship for an individual firm was characterized as follows:

$$R - V_a - V_r - T = D + E \ ,$$

where R = revenues of the firm,

V_a = cost of inputs,

and all other variables are defined above. By rearranging terms and using the first relationship, we have the following:

$$Y = R - V_r \ ,$$

which is the second mesoeconomic relationship, relating gross output to the cost of inputs and revenues of individual establishments in the economy.

The identity derived from the preceding relationships,

$$V_a + D + T + E = R - V_r \ ,$$

defines both the internal operations of a firm ($V_a + D + T + E$) and the external conditions ($R - V_r$) as manifested in markets and suppliers. The relationship was used to define four factors of vulnerability in the economic system. By assuming that D and E both are a function of capital (K), V_a is a function of labor (L), and T is a function of all factors, the four factors of vulnerability are K, L, R, and V_a. The four factors of vulnerability were linked to one another by six ratios: (1) L/K, (2) V_a/K, (3) K/R, (4) V_a/L, (5) L/R, and (6) V_a/R.

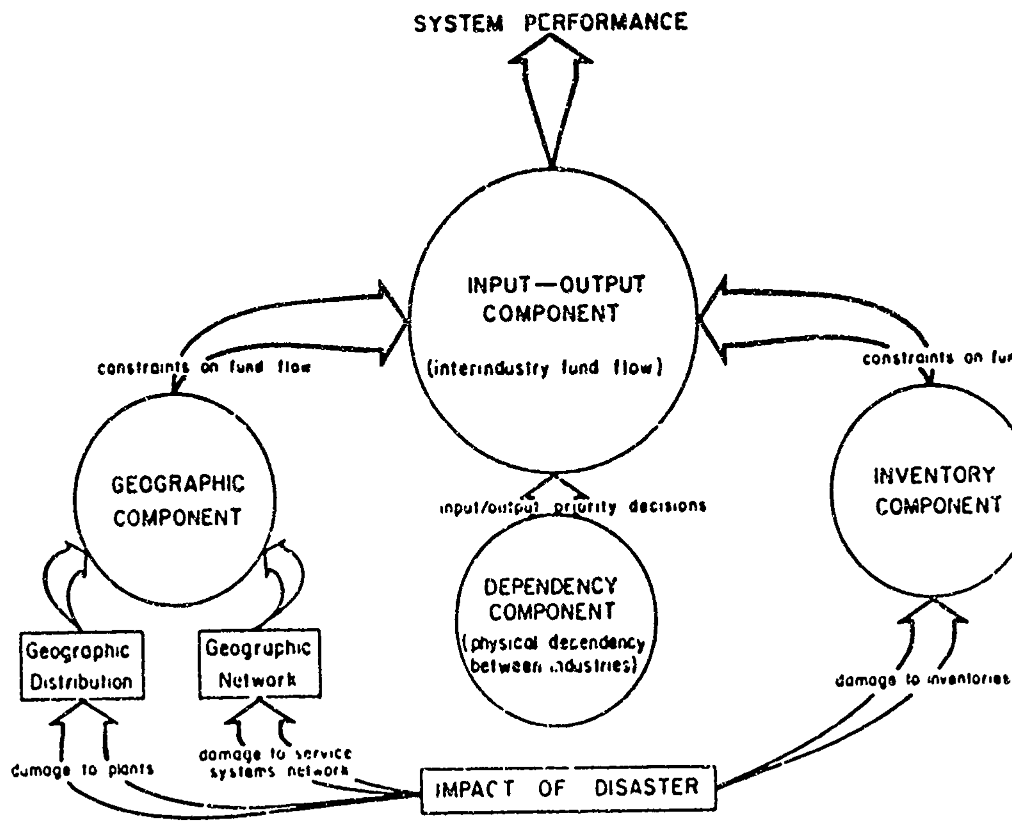
Using this characterization of the economic system, the model incorporated mesoeconomic factors which relate regional income statement variables to the corresponding national variables. Three damage levels were incorporated in the model to characterize the destruction of economic resources: minimum, maximum, and probabilistic damage levels. Minimum damage is simply the largest percentage damage to any one of the four vulnerability factors. Maximum damage is the sum of damage to the four vulnerability factors (not to exceed 100 percent). Probabilistic damage levels are based on an estimation scheme developed by the authors.

While the model can be applied to the economy as a whole or any subeconomy where appropriate data exist, the authors applied the approach to the New Orleans OBE area. A hypothesized attack of 10.8 megatons was the assumed disaster scenario. The authors used national data for the four factors of economic vulnerability (capital, labor, revenues, and the cost of inputs) and applied the relationships between these factors to data on 32 sectors in the New Orleans OBE area. The results showed that the New Orleans OBE area would produce 57 percent of its preattack share of gross output in the aftermath of the attack.

Minor, Lambert and Smith (1972) of Texas Tech University developed a multicomponent model which could be used to simulate the effects of any type of disaster on a regional manufacturing system. The system was applied to the Louisiana-southern Mississippi area. The modeling system was comprised of four components: an input-output system, a geographical

component, a dependency component, and an inventory component. Figure 4.1 provides a schematic representation of the modeling system.

Figure 4.1
A Regional Multicomponent Manufacturing Model



SOURCE: Minor, Lambert, and Smith (1972), Figure 1, p. 5

The input-output component was comprised of 29 standard industrial classification sectors. The 29 sectors selected for incorporation in the Louisiana-southern Mississippi area were selected on the basis of their importance in the regional economy. The input-output matrix reflected interindustry flows in terms of funds (dollars) and were computed largely on the basis of national input-output coefficients.

The geographic component was composed of two parts--geographic distribution and a geographic network. The geographic distribution portion is a 77x29 concentration matrix, representing the 77 counties in the Louisiana-southern Mississippi area and the 29 economic sectors in the model. Each cell in the matrix represents the concentration of total plants and employees for each county-sector included in the system. The geographic network characterizes physical links between geographical areas. The physical links are service systems such as a highway or

power network. The entries take on values from 0 to 1 with the former depicting total inoperability and the latter representing normal operations.

From Figure 4.1, a separate 29x29 dependency component of the system established interindustry dependency on physical commodities. The dependency matrix was developed judgmentally by examining input-output coefficients, the relative importance of an input to sectoral output, and temporal considerations in production. The purpose of the dependency matrix was to establish the physical dependence of one sector on another.

The inventory component provides the value of inventories for each of the 29 sectors. Inventory levels are included to recognize the disequilibrium between inputs and outputs at any point in time. Inventory data for the 29 sectors in the Louisiana-southern Mississippi region were obtained by disaggregating national inventories by sector, using the fraction of total national employment accounted for by the sector in the region as the disaggregation factor.

The authors used the model to conduct two sensitivity studies and to simulate the results of a hypothetical disaster in a specific section of the Louisiana-Southern Mississippi region. The sensitivity studies were based on constraining the output of a sector that receives a large input from outside the region and a sector that produces a large amount within the region. The disaster scenario, which could be attributable to natural causes or nuclear effects, was based on totally eliminating the manufacturing output of several sectors (other fabricated metal products, primary iron and steel, and inorganic and organic chemicals) in Orleans County, Louisiana. The results of the simulation showed that every sector except one was affected by the reduction in Orleans county output, with the printing and publishing and tires and inner tubes sectors the most severely affected outside of the sectors that were assumed destroyed in Orleans County.

In another model development activity, Lambert and Minor (1975a) developed a prototype resource systems regional model and applied it to the Louisiana-southern Mississippi area. The model was developed to assess the vulnerability of manufacturing systems. The results were then intended to be used to develop civil defense countermeasures that could mitigate the adverse effects of the disaster. In contrast to Lambert and Minor's earlier regional models which emphasized economic flows between sectors, the resource system approach is based on physical flows between sectors.

The foundation of the modeling system was the integration of prior research on the vulnerability of specific resource systems--manufacturing, electricity, oil and gas, transportation, and water supply and sewerage--into a total systems model of the region. The rationale for this approach was that an economic system is composed of subsystems, and a simple analysis of the vulnerability of the subsystems independently will not provide insight into the vulnerability of the total system.

Under the approach, a regional resource system was divided into producing systems (manufacturing system) and support systems (electric power, transporation, oil, coal and gas, and water/sewerage). An individual manufacturing operation was characterized by six elements--facilities, personnel, materials, information, money, and energy. A manufacturing system, which is composed of individual manufacturing operations, was characterized by a triad. The triad consisted of inputs, thruputs, and outputs. Another component, crossflow, which is not transformed into output, also was embodied in the system. Therefore, a manufacturing operation was characterized by inputs of raw materials, crossflow (electricity, transportation, fuel, and water), and thruput (human resources, equipment, and facilities). A detailed data base on the manufacturing region under consideration is required to use the system. Data requirements include the number and size of all industries within the region, their location, and intermediate input requirements. A schematic representation of the system is provided in Figure 4.2.

There are three steps in using the model. First, a disaster scenario is imposed. Second, thruput and crossflow analyses are conducted. Finally, an evaluation of the manufacturing system is made. Crossflow analyses include electricity, transportation, fuel, and water/sewerage. Thruput analyses include facilities, equipment, and human resources.

The scenario used for demonstration of the model was a hypothetical nuclear attack that affected 5 of the 77 counties that comprise the Louisiana-southern Mississippi region. The authors concluded:

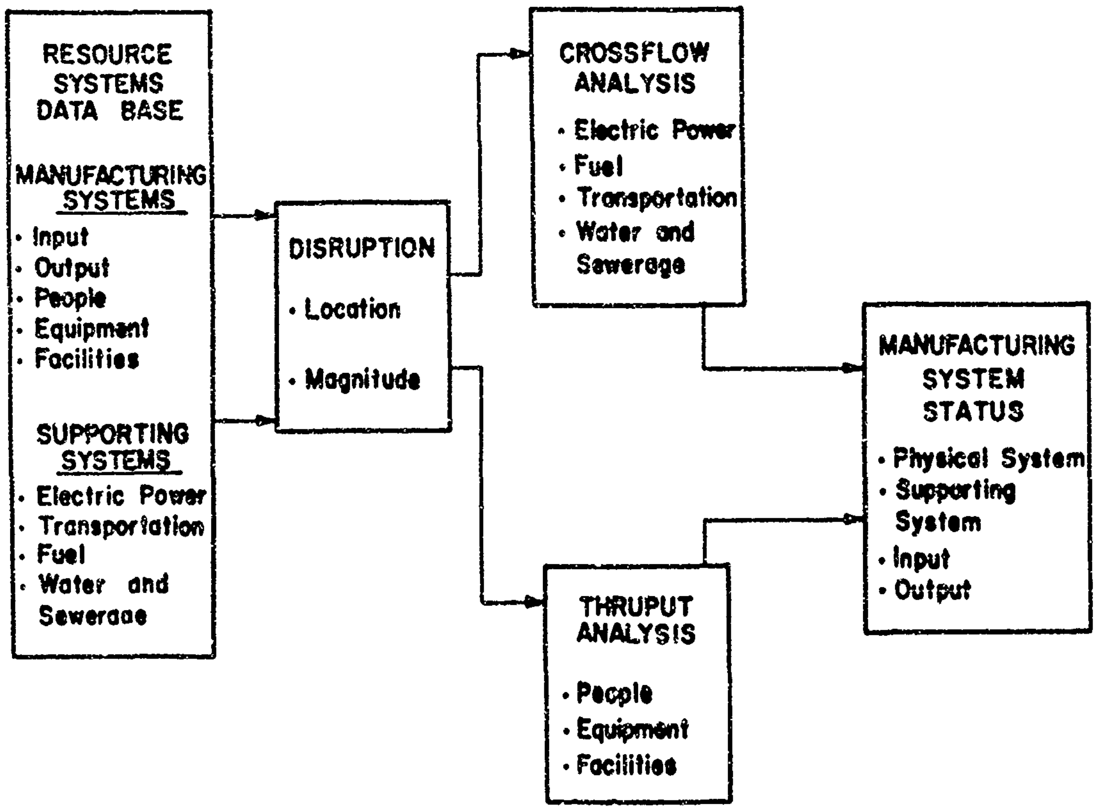
> If subjected to a nuclear attack which produces the disruptions (discussed in the report), the manufacturing system would be severely damaged (through direct and systemic effects) and the region could not be expected to sustain itself in the immediate postattack period. The imposition of CD actions could, however, preclude this situation, if appropriate steps were taken in the preattack time period. Direct CD actions involving stockpiling of inventory could reduce postattack input related constraints, and personnel relocation actions (such as CRP) could relieve postattack constraints on human resources. (Lambert and Minor, 1975a, p. 73).

As part of a larger investigation of various aspects of natural hazards, Cochrane (1975) simulated the economic effects of California earthquake hypothesized to occur in 1975.* The earthquake was similar in magnitude to the earthquake that San Francisco experienced in 1906. To capture both the primary and secondary economic effects of the disaster, he used a linear program to estimate the effects after the first year following the disaster. Unfortunately, the approach was not documented in detail sufficient to identify problems with individual sectors of the economy. However, he found that the economy would experience a $6 billion reduction in value added in the first year after the earthquake, reducing the preattack level from $22 billion to $16 billion.

---

*The same results are contained in an earlier work [see Cochrane et al. (1974)].

Figure 4.2
A Resource Systems Regional Model



SOURCE: Lambert and Minor (1975a), Figure 5, p. 28

In a later paper, Cochrane (1984) acknowledged the limitations of using fixed production coefficients to determine the secondary effects of a disaster on a local economy. To correct for this problem, he developed a general equilibrium model of a local economy. The foundation of the model was a representation of producer and consumer behavior rooted in neoclassical economic theory. The production function and utility function took the following form:

$$Y_j = \left[a_{0j} + a_{1j}L_j^{-\sigma_j} + a_{2j}K_j^{-\sigma_j}\right]^{-1/\sigma_j} \text{, and}$$

$$U = \sum^{i}[\beta_i \ln(Yd_i - \tau_i)] \text{,}$$

where Y_j = output in sector j,

L_j = labor used in sector j,

K_j = capital used in sector j,

a_{0j} = return to scale parameter,

a_{1j} = labor share parameter,

a_{2j} = capital share parameter,

σ_j = elasticity of substitution of labor for capital,

U = utility,

Yd_i = consumption of good i,

τ_i = minimum amount of i acceptable, and

β_i = weight given to i.

Using the constant elasticity of substitution sectoral production functions, Cochrane assumed that producers maximize profits by equating the marginal revenue product of labor and capital to their respective prices. Prices were determined as follows:

$$P_i = \Sigma P_j a_{ij} ,$$

where P_i = price of consumer good,

P_j = price of intermediate good, and

a_{ij} = amount of i required per unit of j.

Consumers were assumed to maximize utility subject to a budget constraint, yielding Marshallian demand curves:

$$Yd_i = \tau_i + (\beta_i/P_i)(Ydisp - \Sigma P_i \tau_i) ,$$

where Ydisp = income devoted to consumption.

The regional income constraint was specified as follows:

$$Ytot = [\Sigma^{j} L_j \bar{w} + K_j^0 P^0 cr + dK_j P'cr + \pi_j] ,$$

where Ytot = total regional income,

$\bar{w}$ = wage rate (assumed the same across sectors),

K_j^0 = initial capital stock,

P^0c = initial supply price of capital,

r = interest rate,

dK_j = investment in sector j,

P'c = postdisaster supply price of capital, and

π_j = profit in sector j.

The model included a trade sector that contained a demand curve for the region's products and a demand curve for imports into the region. The export sector included a linear demand function for the region's products with the export price as the sole argument in the function. For the import sector, it was assumed that there is a perfectly elastic supply of imports if the price is greater than the existing price in the region. Imports were modeled as the difference between the amount produced in the region and the quantity demanded.

Taxes were assumed to be a fixed percentage of total income in the region and government spending was exogenous to the system. Supply and demand are equilibrated in all markets and, to ensure that income is fully allocated, the following relationship was included:

$$\Sigma S_i + T + \Sigma(Yd_j - Ys_j) = \Sigma G_j P_j) + ExP_x + Inet ,$$

where S = savings,

T = taxes,

Yd_j-Ys_j = imports,

G_jP_j = government expenditures in sector j,

Ex = exports,

P_x = price of exports, and

$Inet$ = net investment over all sectors.

Cochrane argued that the true measure of loss in the aftermath of a disaster is the compensation required to restore consumers to their pre-disaster level of utility. In a Marshallian demand framework, this is simply the concept of compensating variation.

Cochrane simulated the aftermath of a disaster with hypothetical data. Based on the simulations, he concluded that a disaster's effect on a regional economy could be explained by the marginal utility of income, the elasticities of substitution in both consumption and production, interregional price differentials, and limited labor and capital mobility. He concluded:

> The most important of these factors is capital mobility. It would not be difficult to prove that in the absence of adjustment costs, that is, if replacement capital could be installed quickly at a cost equivalent to that of the damaged capital, then the CV (compensating variation) and capital loss would be one and the same. Furthermore, it could be demonstrated that the form of aid to the region would not influence welfare. It should make no difference whether cash, physical capital or consumer goods is provided; the effect on CV will be the same. (Cochrane, 1984, p. 15).

Munroe and Ballard (1983) simulated the economic effects of a hypothetical earthquake in the San Francisco Bay area. The magnitude of the earthquake was similar to the one that the area experienced in 1906. The authors used the California County Area Multiregional Modelling System (CAMS) to simulate the economic effects of the hypothesized disaster.* CAMS is a detailed model of the California economy that emphasizes county-level economic activity. Each of the 58 counties in the state is characterized by 35 behavioral equations, 110 identities, and five exogenous variables.

The model combined features of both a "top down" and "bottom up" modeling approach. For the former, the performance of some of the sectors in the economy were derived from national economic activity. For the latter, economic activity in some industries was determined at the local level. The behavioral equations in the model were a function of national, local, and interregional explanatory factors. Employment equations, wage rate equations, demographic equations, commercial and building sector equations, and government finance equations were estimated for each of the counties included in the system.

The authors reported simulation results for both one and five years after the hypothetical earthquake. The results of the simulations showed that the state of California would experience a $24 billion loss in income over the five-year period after the earthquake. More than one-half of that amount would occur in the first year. With respect to employment, 588.6 thousand jobs would be lost in the five-year period. The loss in the first year would be 312.6 thousand. For both income and employment, the vast majority of economic losses would occur in the six-county San Francisco area.

Ellson, Milliman, and Roberts (1984) developed an econometric model of the Charleston, South Carolina standard metropolitan statistical area (SMSA) to simulate the economic effects of an earthquake over the 1981-1990 period. The four reported simulations included a baseline simulation (no earthquake predicted or occuring over the 1981-1990 period); an unanticipated earthquake in 1983; an anticipated earthquake predicted in 1981 that occurs in 1983; and an earthquake predicted in 1981 for 1983 that does not occur. The latter three simulation results were compared to the baseline forecast.

The system used for simulation included a model for each of the three counties that comprise the Charleston SMSA and linkages between the three counties. The specification of each county model incorporated employment, income, and government blocks. The employment block segregated economic activity between export-based and local industries on a one-digit SIC sector basis. The income block determined wages and salaries and other nonwork income. The government block represented fiscal activity--revenues, expenditures, and debt. The individual county models also included a housing sector, capital stock and investment, migration, transportation flows, and capital flows. The driving force of the

---

*A detailed description of the model can be found in Ballard (1983).

estimated equations were 22 exogenous variables, 11 of which were national in scope (GNP, for example).

Based on a comparison of the simulation results of the three earthquake scenarios with the baseline simulation over the 1981-1990 period, the authors concluded in part:

> . . . one is struck by the resiliency of the regional economy and its ability to recover from an earthquake disaster and the prediction of one even when pessimistic assumptions are employed. What is clear is that the health of the regional economy is determined more by the assumptions one makes about the national (exogenous) growth factors driving the regional economy than by the disruptive effects of an earthquake whose severe effects are largely temporary and tend to diminish over the longer run. (Ellson, Milliman, and Roberts, 1984, p. 570).

4.2. STUDIES USING NONMODELING METHODS

The purpose of this section is to provide an overview of 17 studies of regional or local economies in the aftermath of a disaster. The first six studies discussed in the section addressed some aspect of regional/local economies in the aftermath of a hypothetical nuclear attack. The regions under consideration are San Jose, Detroit, Houston, the state of Ohio, and the New England area. The remainder of the studies addressed the economic effects of regional/local economies in the aftermath of natural disasters. The primary method of analysis in these studies is examination of economic time series to ascertain the effect, if any, that the disasters had on the regions in both the short and long term.

In one of the earliest studies of the economic effects of nuclear attack, Paul Clark (1956) of the Rand Corporation developed a methodological approach to study the recovery potential of regions after an attack and applied it to the New England area. The area under investigation included the metropolitan areas of four cities (Boston, Providence, Springfield, and Hartford), 14 smaller cities (New Haven and Pittsfield, as examples), and 17 county areas. Clark investigated the effects of two hypothetical attacks, each of which had two variants--a warning variant in which evacuation allows 75 percent of the population in affected cities to survive and a surprise variant that results in only a 25 percent survival rate. One of the hypothesized attacks was on the four large metropolitan areas and two bordering ones, while the other scenario also included 14 other smaller metropolitan areas. In all attack scenarios, it was assumed that the remainder of the United States was also attacked. The effects of radioactive fallout were not considered. The scope of the study included an examination of the preattack New England economy and a nonmodeling quantitative analysis of the postattack economy.

In the preattack economy, Clark analyzed the concentration of important economic resources. The major concentrations of economic resources were found to be in wholesale trade and wholesale inventories,

water transport, steam electric power generation, and banking services. The most important dispersed resources were truck transport, hydroelectric-generated power, and building materials. The most significant aspect of the region's economy from an attack standpoint was its reliance on the imports of important commodities. One-half of the food supply, nearly all fuel requirements, and the majority of industrial raw materials were acquired from areas other than the New England region at the time of the study.

One of the effects of the light attack with warning would be an increase in the region's population because of the in-migration of refugees. Industrial capacity across sectors would be 50 to 90 percent of preattack capacity and inventories of food and clothing would be tight even with a rationing program in effect. The critical problem for economic recovery in the region would be the availability of petroleum products and metals on a national level. Under the light attack without warning scenario, the major problem would be medical-related. By dividing the economy into the impact period--approximately the first two months after the attack--and the recuperation period, Clark concluded that the functioning of the economy under this scenario would be similar to the warning scenario because the larger destruction of railroads and trucks would be offset by lower import requirements. Under both heavy attack scenarios, the economic recovery prospects would be qualitatively similar but quantitatively more severe than the light attack scenarios. One of the most critical problems would be transportation capacity. Based on his analysis, Clark made this policy prescription:

> Stockpiling in dispersed locations would be particularly important for medical supplies, preserved food, and repair materials like wire and rails. Advance plans are particularly needed for guiding refugees and allocating housing, for immediate and stringent rationing of food and clothing, for alternative governmental and banking organizations, and for coordination of trucking operations. (Clark, 1956, p. 93).

William C. Truppner (1965) of the Institute for Defense Analyses estimated the economic impact of hypothetical nuclear strikes on the Houston, Texas metropolitan area. The study was focused on three components of the Houston economy: (1) property values, (2) economic output, (3) and the population/labor force.

Categories of property included in the study were real estate improvements; machinery, equipment, and inventories; nontaxable property; and household furnishings and automobiles. In the analysis, all classes of property were assigned to a 65x65-square-kilometer grid of the Houston area and 16 different hypothetical attacks were imposed on the city area--eight weapon yields (0.1 megaton to 100 megaton) and two population assumptions (at-home, at-work). Using a step function to assess blast damage, Truppner found that surviving physical property under the most severe attack scenario (100-megaton, at-work) left only 10.3 percent of preattack value. Under the lightest attack (0.1-megaton, at-home), 94.4 percent would survive.

Truppner measured economic output in the Houston area in terms of value added for the manufacturing and mining sectors and wages and salaries for all other sectors. Damage levels were classified as no damage, light damage, moderate damage, and heavy damage. It was concluded that only 33.1 percent of output would be available after a 10-megaton attack and 62.8 percent after a 0.5-megaton attack. The largest damage levels would be sustained in wholesale and retail trade, the finance sector, and the construction industry.

For the population/labor force portion of the study, Truppner considered a 10-megaton attack under two protection scenarios--at-home with no special shelters and a fallout shelter scenario. The results of the analysis suggested that population protection measures reduce both population vulnerability in terms of fatalities and the distribution of population across industries and skill levels.

Truppner concluded that the results of more aggregated, national studies of vulnerability may be overly optimistic on economic recovery prospects:

> Assuming that such a situation would be characteristic of every target city in a nuclear attack, it would appear that important tears in the fabric of the nation's industrial strength are obscured by analyses that employ only nationwide aggregation. This finding has obvious implications for judgments based on estimates of post-attack economic output developed from statistics reflecting national totals. (Truppner, 1965, p. 51).

Stephen L. Brown (1966a) of the Stanford Research Institute examined the industrial recovery potential of the standard metropolitan statistical area of San Jose, California in the aftermath of a hypothesized nuclear attack. He compiled data on manufacturing plants within 21 miles of ground zero in order to assess fire and blast damage from the same hypothetical attack specified for the area in the Five-City study.* The attack was a five-megaton airburst near Moffett Field in south San Francisco Bay. Data compiled for the study included number of employees, location of plants, characteristics of structural materials, and equipment and materials used in manufacturing. Based on a detailed assessment of the effects of the hypothetical attack scenario, he concluded that

> . . . 58 of the 146 facilities might be essentially destroyed by sustained fire and that an additional 11 sites could incur very heavy blast damage even without fire. Thus, about half of the facilities, employing about two-thirds of the total manufacturing workers, could be recovered only through complete reconstruction. (Brown, 1966a, p. 22).

---

*The Five-City Study was a wide-ranging research effort on the effects of nuclear attack in five cities--Detroit, Providence, San Jose, Albuquerque, and New Orleans. An overview of the study can be found in Kerr, Harker, and Rockett (1967).

In one part of a two-part study that comprised a portion of the Five-City Study, Andrew Pryor, George Commerford, and Joseph Minor (1968) of the Southwest Research Institute conducted a detailed assessment of one manufacturing complex in San Jose, California--the United Centrifugal Pumps Plant Complex. The purpose of the study was to determine the effects of a nuclear attack on property, people, and systems. The estimation of damage that was directly and indirectly attributable to nuclear blast was based on other damage assessment studies.

Based on a five-megaton airburst attack scenario, the authors estimated that the plant could operate at 60 percent of preattack capacity immediately after the designated attack with an estimated 38 percent loss in personnel. Particular problems that could arise in the postattack period are related to organizational arrangements. Specifically, management of the plant would be required to know their exact production mission in the postattack period in order to obtain necessary inputs (labor, utility services) and to determine output priorities. In large measure, this would have to be accomplished in preattack planning.

The selection of one manufacturing complex for detailed analysis was the result of a detailed analysis of nationally critical industries that the authors conducted in the first part of the research. The United Centrifugal complex represented a composite of five critical industries the authors identified in their research: (1) valves and pipe fittings, (2) farm machinery and equipment, (3) pumps and pumping equipment and air and gas compressors, (4) general industrial machinery and equipment, and (5) miscellaneous machinery except electrical. The United Centrifugal complex was considered a composite because it produced the five commodities considered critical for postattack recovery.

The selection of critical industries was based on a comprehensive analysis of industrial activity in five standard metropolitan statistical areas incorporated in the Five-City Study: Detroit, San Jose, New Orleans, Albuquerque, and the Providence-Pawtucket area. The selection of critical industries was based on primary and secondary criteria. The former included the needs of the postattack economy (food, housing, communications, transportation), extent of stockpiling, and the commonality of usage of the commodity.

In a subsequent study at the Southwest Research Institute, Minor, Pryor, and Commerford (1969) expanded their work from analysis of a single plant to postattack problems in an industrial area. The purpose of the study was to develop a methodology for analyzing the effects of an attack on the operation of manufacturing systems within an industrial region. The authors maintained that, while analyses of national systems can be an important source of gross appraisals, more disaggregated analysis is required because local interdependencies could be a source of problems that are masked in national studies. The authors applied their approach to the Detroit area industrial system to demonstrate a methodology that could be applied in other areas. The primary reason for selection of Detroit was its inclusion in the Five-City Study.

The authors used a four-step procedure. First, the industrial systems were defined. A data base was developed to document both physical

facilities in the industrial region and personnel. Second, industrial interrelationships were determined. This step involved defining the manufacturing link between systems. Third, essential industries were selected on the basis of national needs, local needs, and industrial interrelationships. Seven sectors satisfied the criteria: five durable goods industries (metalworking, industrial machinery, electrical equipment, stampings, and primary iron), rubber, and chemicals. Finally, the effect of an attack was analyzed.

An attack scenario was imposed on the area and the ensuing damage to 49 plants in a selected industry (screw-machine products) was examined to determine the postattack effects. The attack scenario imposed was the same one used in the Five-City Study for the Detroit area--a five-megaton ground burst in Southwest Detroit. Based on a detailed examination of the screw-machine products industry, the authors concluded in part:

> Damaged and contaminated plants are able to resume production within a few weeks or months; however, destroyed plants are not able to recover so quickly. Only a few of the large number of surviving employees from the large downtown plants that were destroyed can be relocated to these repaired plants to bring staffs back to preattack levels. (Minor, Pryor, and Commerford, 1969, p. 90).

The System Planning Corporation examined the extent to which the population would survive in the first year after a nuclear attack [Roger J. Sullivan et al. (1979)]. Rather than analyze the entire United States, the authors selected Ohio as an "index state" for the country. The authors examined the effectiveness of preventive measures that potentially could ameliorate problems associated with recovery. If no protective measures were taken (e.g., Program D-Prime crisis relocation), only 20 percent of Ohio's population would survive. If program D-Prime were implemented, 80 perecent of the population would survive. The authors concluded that lack of food may be the biggest problem for continued survival.

Kunreuther and Fiore (1966) studied the Alaskan economy in the aftermath of the March, 1964 earthquake in that state. The authors characterized the long-term recovery of an economy in the aftermath of a disaster in terms of the capital-to-labor ratio. Their hypothesis was stated as follows:

> If a disaster lowers the capital/labor ratio--i.e., results in large physical losses but few losses of human resources--recovery will be rapid if external funds are made available. If external funds are limited or difficult to obtain, recovery from similar destruction will be slow. (Kunreuther and Fiore, 1966, p. 49).

The authors concluded that this characterization of the recovery process explains the relative difference between rates of recovery in the Anchorage area and outlying communities in Alaska. Based on examining labor and capital changes in Alaska in the aftermath of the earthquake,

the authors concluded that the large injections of capital in the Anchorage area explain the relatively quick recovery of that region.

In a later study, George W. Rogers (1970) of the University of Alaska examined the short run and long run impact of the 1964 earthquake in Alaska and corroborated Kunreuther and Fiore's conclusion on the Anchorage area. Rogers analyzed key aggregate macroeconomic indicators over both a period of years and a period of months preceding and following the earthquake. The principal variables that Rogers considered were population and employment by sector in the Anchorage labor-market area. Anchorage was chosen because the hardest hit area of the earthquake was the South central region of Alaska and the Anchorage area comprised over 80 percent of nonagricultural wage and salary employment of that region at the time of the disaster.

Based on his analysis of the data, Rogers concluded:

> Although value of property damaged and destroyed was high in relation to Alaska's population and income base, recovery of the economy following the great Alaska earthquake of 1964 was rapid and the activities engendered gave employment and income an important boost over previous levels. (Rogers, 1970, p. 58).

Rogers attributed this phenomenon to the peculiar nature of the Alaskan economy. Since the Alaskan economy was based in large measure on government-related activity as opposed to manufacturing activity, there was little need for rebuilding industrial capacity and the infusion of federal money into the economy ($321 million over a 30-month period) acted as a big stimulus to growth. The construction industry in particular benefitted. Construction employment rose 60 perecent in April 1964 over the preceding month and 80 percent over the same month in the previous year.

Dacy and Kunreuther (1969) examined the short-term and long-term recovery of communities after natural disasters with special emphasis placed on the recovery of Anchorage after the earthquake of 1964. After analyzing price behavior in the immediate aftermath of a disaster, the authors concluded:

> Because the availability of outside aid tends to make supply very elastic, shortages of resources are felt to be short lived. This promise of support by nonaffected regions is yet another element in the pattern of disaster response indicating that economic behavior during the recuperation period is influenced by sociological and psychological factors. (Dacy and Kunreuther, 1969, p. 120).

For long-term recovery from natural disasters, the authors compared the reconstruction of Anchorage and Skopje, Yugoslavia and examined the reconstruction in the aftermath of other disasters. Based on their statistical examination of restoration efforts, the authors concluded:

> Despite the large amount of destruction caused by a disaster, we have shown that recovery can be rapid if capital in the form of loans and grants is readily available. In fact, a disaster may actually turn out to be a blessing in disguise. Aside from the economic boom that often follows because of the large amount of reconstruction, there is an opportunity for commercial establishments and homeowners to improve their facilities. (Dacy and Kunreuther, 1969, p. 168).

Brannen (1954) analyzed the short term economic effects of the tornado that struck Waco, Texas on May 11, 1953. He examined statistics on retail sales and employment to ascertain the effects of the tornado on the local economy. Based on his analysis, Brannen concluded:

> . . . aggregate community income experienced only a minor decline, and sufficient retail outlets remained undamaged to permit a rapid return to near normal activity on the part of the majority of the community. As a result, business recovery from the tornado was amazingly rapid. For example, retail sales and employment virtually had returned to normal at the end of two months. (Brannen, 1954, p. 27).

Black (1970) examined the economic recovery of the Mississippi Gulf Coast one month after Hurricane Camille. On-site investigations and interviews to determine the recovery efforts of food processors, manufacturing facil'ties, and public utilities were the basis of his analysis. Emphasis :as also placed on debris clearing operations. One of Black's primary recommendations was that civil defense activities should be involved with continual analysis of recovery efforts in the aftermath of disasters. The analyses should document recovery activities and provide information for data banks that would be used as a source of information for civil defense planning.

Minor, Lambert, and Wittman (1972) of Texas Tech Univeristy assessed the effects of the May 11, 1970 storm in Lubbock, Texas on supporting utilities, the manufacturing sector, and the regional economy. The tornado occurred in the evening at the center of the commercial and business district. It affected approximately one-fourth of the city. One of the primary purposes of the research was to assist disaster planners in identifying areas of the regional economy most vulnerable to local disaster damage.

The authors compiled a data base of 493 firms by standard industrial classification (SIC) code in the Lubbock area. Each of the firms experienced some degree of damage in the storm. Based on analysis of the data, the authors concluded that fabricated metal products and machinery, except, electric experienced the severest direct damage from the standpoint of interrupting production. In terms of damage because of the failure of supporting systems, the authors found that food and kindred products, printing and publishing, and petroleum refining and related products suffered the most damage primarily because of failure of electric power systems. With respect to analysis of time series economic indicators to determine the effect of the storm on the regional economy, the authors concluded:

> It is difficult to determine from reviews of the various economic indicators that a disaster occurred, except for a brief period immediately following the date of the storm . . . The regional economy sustained an immediate disaster induced disruption, but the long term effects of the disaster cannot be detected in yearly compilations of economic indicators.

Douty (1977) examined both the short- and long-run economic consequences of the 1906 earthquake in San Francisco. Based on an examination of prior studies of the disaster and statistical information for the period, Douty concluded that in the immediate short run the market mechanism ceased to function, but the free market was allowed to allocate resources for the short-run rebuilding effort. Based on an examination of industry, land use, and population in the long run, Douty concluded that a disaster is insignificant for economic growth:

> On the basis of the San Francisco evidence, a localized disaster does not appear likely to alter long run economic trends; such trends almost surely were not changed in San Francisco. The disaster did stimulate population dispersal. It hastened the decline in the relative importance of manufacturing in the city's economy. There is no obvious answer to the question of whether lasting economic improvements resulted from the disaster, which suggests that such improvements, if any, were minor. (Douty, 1977, p.369).

H. Paul Friesema et al. (1979) studied the short- and long-range economic effects of four natural disasters. The disasters included the Yuba City, California flood of December, 1955; Hurricane Carla on Galveston, Texas in September 1961; the tornado in Conway, Arkansas in April, 1965; and the tornado in Topeka, Kansas in June, 1966.

For the long-range effects of the disaster on the four locales, the authors examined four indicators of economic performance: employment, sales patterns, small business survival, and local taxes and expenditures. The methodology employed to examine the disasters' effects on employment was to estimate ordinary least squares regression equations for employment series data both prior to the disaster and after the disaster. The estimated equations were compared statistically to see if the structure of the economies had changed. The methodology used for the other three series--sales patterns, small business survival, and local taxes and expenditures--was to observe the series over a period of years. Based on their analyses, the authors concluded:

> Our examination of employment and workforce changes initially does suggest some consequences of the disaster event for the local labor market and labor force. Yet a closer examination of these data caused us to conclude that secular changes--rather than the disaster event itself--were probably responsible for the observed shifts. . . we conclude that none of the economic indicators on which we have collected data suggest that natural disasters leave profound, lingering effects on these local economies. (Friesema et al., 1979, p. 84).

For the short-range effects of the disasters, the authors developed a univariate econometric time series model to estimate effects in the month of the disaster, a period of months following the disaster, and the rate at which the effects of the disaster atrophy. The authors concentrated on employment time series. For the Topeka workforce, the authors found a permanent, but not significant, change following the disaster. For the Galveston disaster, the authors found an erratic performance after the disaster but the net effect was negligible. The Yuba City results also exhibited very little effect of the disaster.

James D. Wright et al. (1979)* analyzed the long-term effect of natural disasters on census tracts, counties, and standard metropolitan statistical areas of the United States over the period 1960 to 1970. Their approach was to develop a comprehensive data base of all of these subdivisions in the United States and econometrically estimate the impact of disasters on these areas. Using primarily census data for 1960 and 1970, the authors developed data on a number of socioeconomic characteristics of the region. Econometric models were estimated to see if a natural disaster had an impact on indicators of performance of the community in relation to other communities or regions that did not experience a disaster. The indicators included population and housing. Concisely, the approach measured the effects of disasters on characteristics of the regions in 1970, econometrically controlling for differences in those communities in 1960. The disasters considered were tornadoes, floods, and hurricanes.

The results of the econometric analysis suggested that natural disasters do not pose any long-term threats to the communities in terms of population and housing characteristics. With respect to the county level analysis, the authors concluded:

> For the entire set of counties, there are no significant effects of disasters on growth trends in population and housing. Why? First, damages from the average disaster are very small in relation to the population base and housing involved, even in the rural counties. Second, for the small subset of truly serious disasters, relief policies in effect during this period may have provided enough additional support for reconstruction to dampen considerably the lasting effects of the disaster events . . . In short, our finding is that <u>disaster events have no discernible, consistent effects on counties that survive more than a very short period of time</u>. (Wright et al., 1979, p. 152).

The results were not significantly different using a similar type of econometric analysis for census tracts. The authors concluded:

> All told, our search for disaster effects among tracts has revealed very little. For tracts as a whole, there are no discernible effects on growth trends for housing or population: tracts that experienced disaster events did not grow at either

---

*A version of this study also appears in Wright and Rossi (1981).

a faster or slower rate than nonhit tracts of comparable composition and location. (Wright et al., 1979, p. 174).

Rubin (1981) examined the long-term economic recovery from six unnamed natural disasters. The disasters were evaluated on the basis of seven specific factors related to the disaster. Included among the factors were size of the disaster, response, prior experience with disasters, familiarity with external aid programs, leadership, intergovernmental relations, and the commitment to mitigating the disaster. It was concluded that the two primary determinants of recovery were experience with prior disasters and a working relationship with state and Federal governments:

> For the most part, prior disaster experience led to greater knowledge and application of mitigation measures. Further, the earlier experience(s) provided opportunities for local officials to meet the key decisionmakers at each level--such contacts became very useful the next time outside assistance was needed. (Rubin, 1981, p. 18).

Harbridge House examined the economic effects of natural disasters on small to medium sized communities. Their approach was to examine three economic time series for 16 communities affected by natural disasters. The three indicators--unemployment, disposable income, and percentage of low income population--were examined both prior to and two years following the disaster. Additionally, they undertook three more in-depth studies of regions affected by disasters, using various economic indicators to ascertain the impact of the disaster.

Their analysis of the 16 communities showed that nine cities exhibited an increase in two indicators of economic performance two years after the disaster, while five cities showed a decline in two indicators over the same time period. One city exhibited an improvement in all three indicators, and one city declined in all three indicators. This led the authors to conclude:

> This alarmingly high percentage of communities which clearly do not regain their past economic strength raises real cause for concern. The data suggests serious questions not only about the impact of a disaster but also about the nature of assistance intended to provide for recovery. (Harbridge House, p. III-12).

Recognizing that aggregate economic data do not provide much information on the causal relationships in the recovery from disasters, the authors further examined three communities affected by disasters. Those communities included Alaska after the 1964 earthquake, Corpus Christi, Texas after the 1970 hurricane, and the Wyoming Valley area of Luzerne county in Pennsylvania after Hurricane Agnes in 1972.

Based on the aggregate statistical analysis of the 16 communities and the more in-depth analysis of three disasters, the authors concluded that the basic factor in economic recovery potential of a region in the aftermath of a disaster hinges on the nature of the industrial base of

the community and the factors of production that are used in the community. The authors concluded:

> Any constraint on (capital, labor, inputs, and markets) threatens the basic viability of the industry in the area. To the extent that a disaster creates such constraints, or accelerates already existing ones, its ability to recover from the disaster will be seriously impaired. (Harbridge House, pp. V-3, V-4).

5. PHYSICAL INFRASTRUCTURE: INDIVIDUAL INDUSTRY STUDIES

5.1. INTRODUCTION

The purpose of this chapter is to review prior research on individual industries in the aftermath of a disaster. Although the majority of studies of individual industries have been associated with the blast, fire, and overpressure effects of nuclear attack, many of the results of the studies can be interpreted in the context of natural disasters. The industries under consideration include aluminum, chemicals, construction, drugs and antibiotics, electric power, natural gas, petroleum, process control, rubber, steel, and transportation.* As was the case with the majority of studies reviewed in the previous two chapters, most of the industry studies reviewed in this chapter were conducted in the 1960s and early 1970s. No attempt will be made to conjecture on the applicability of the results of the studies to current conditions in the event that conditions have changed since publication of the original research.

In many respects, research on the vulnerability of individual industries to nuclear attack can be considered as an extension of much of the research discussed in the previous two chapters. That is, many of the modeling and nonmodeling studies discussed in those chapters identified specific sectors of the economy that are critical or essential to economic recovery in the aftermath of a nuclear attack. In large measure, criticality was defined as a potential bottleneck in postdisaster production. The studies of individual industries discussed below were undertaken for the most part because of their assumed importance in economic recovery.

The process of identifying the most critical or essential industries is not straight forward. Jane Leavitt and Abner Sachs [Leavitt (1974), Sachs and Leavitt (1974)], for example, attempted to develop criteria for including industries in a list of nationally essential and locally vital facilities in both preattack and postattack conditions. After examining previous approaches to identifying critical industries, Leavitt concluded:

> . . . national essential facility criteria have to be decided judgmentally in each case, given the data bases that exist; and no analytic, across-the-board criteria can be developed that will mechanically generate a comprehensive list. (Leavitt, 1974, p. 32).

Besides identifying industries of special importance in economic recovery from disasters, research has been undertaken on the vulnerability of individual industries to the effects of a rapid shutdown necessitated by an emergency. In a large study of rapid shutdown techniques,

*Note here the omission of prior studies conducted on agricultural production, food processing and distribution, and water systems. These industries are the subject of detailed analysis in other research that is being conducted simultaneously with this study.

McFadden and Bigelow (1966) classified industries on the basis of their vulnerability to rapid shutdowns. Industries in which a "controlled shutdown" could be accomplished within half an hour were eliminated from consideration. Four categories were developed based on "potential or probable sources of loss." The categories [and industries classified in them] included: (1) major damage and startup difficulty [petroleum refining and petrochemicals, steel (blast furnaces and coke ovens), aluminum (refining and smelting), and explosives (nitroglycerine and TNT)]; (2) minor or moderate damage, with major startup difficulty [iron and steel (conversion furnaces), non-ferrous metals (zinc, copper, and lead), synthetic rubber and plastics, and glass and ceramics]; (3) moderate damage and startup difficulty [electric power (thermal), industrial and agricultural chemicals, sugar refining, and cement]; and (4) minor damage and startup difficulty [food processing, pulp and paper, and soaps and detergents]. The authors concluded that process industries are the most vulnerable to rapid shutdown. They discussed in detail the two most vulnerable industries--petroleum refining/petrochemicals and steel. The results on these latter two industries are presented below.

Still other research has been undertaken on the "hardening" of industrial facilities to reduce their vulnerability to the effects of nuclear weapons. Bickley and Sachs (1966) categorized the 381 four-digit standard industrial classification (SIC) manufacturing industries on the basis of equipment used in production to determine the hardening costs of manufacturing industries. The classification was based on the costs of protecting industrial equipment and processes from the overpressure effects of nuclear blasts. In a later study, Bickley (1967) summarized the characteristics of the 381 industries discussed in the earlier study.

The basis of classification for each of the 381 four-digit manufacturing industries was a matrix of 24 physical characteristics of plant and equipment used in the production process. First, physical characteristics were classified as (1) general purpose--common equipment used throughout industry that performs the same function; (2) special to the industry--used in a specific industry but not in others; or (3) unique to the product--used for a specific product that is indispensable in producing that product. Second, for each of these three categories, equipment was categorized as light or heavy on the basis of physical design. Third, equipment was further classified on the basis of production accuracy or sensitivity to disturbance--"regular" or "precision." Finally, the equipment was categorized as either indoors or outdoors. The equipment was categorized in these 24 classifications on a percentage basis. The results for each of the 381 industries was provided in Bickley and Sachs (1966), Volume II.

Based on this classification, the authors developed a method for estimating the hardening costs of an industry. Concisely, the methodology involves estimating the hardening costs of a few select industries and, using an algebraic relationship expressing the industry in terms of its characteristics, applying these estimates to all of the individual four-digit SIC manufacturing industries.

In a later study, Cannell and Schuert (1980) developed an industrial preparedness program to enhance the capability of the nation to meet its recovery goals in the event of nuclear attack. In many respects, the program that was developed draws upon many of the recommendations made in both the studies reviewed in the previous two chapters and the individual industry studies that are discussed in the remainder of this chapter. The program was developed in the context of expected postattack conditions. To determine conditions in the postattack environment, the authors used the CHARLIE attack scenario of the UNCLEX-73 exercises* under two assumed evacuation scenarios: (1) the population was evacuated under Program D-Prime in which the assumed population survival rate was 80 percent and (2) the population was not evacuated and only 45 percent survived.

The recommended program was developed in the context of three considerations: (1) the Federal Emergency Management Agency's objectives, (2) fifteen countermeasures for industrial preparedness, identified for the most part from the extant literature, and (3) six industries identified in the literature as essential to postattack recovery. These industries included food and water, drugs, transportation, communications, electric utilities, and petroleum. The study provided specific recommendations for FEMA's active participation in countermeasures to protect capacity in the six essential industries.

Included among the studies discussed below are a series of research reports undertaken as part of the Five City Study. The Five City Study was a long-term, wide-ranging, coordinated research effort initiated by the Office of Civil Defense in 1965 on the effects of nuclear attack on five U.S. cities--Detroit, Michigan; Providence, Rhode Island; San Jose, California; Albuquerque, New Mexico; and New Orleans, Louisiana.** For each of the cities, a detailed set of assumed preattack and postattack conditions were provided. They included the nature of the hypothesized bombing attack, the assumed preparations undertaken for each of the cities, the physical effects of the weapons, and a detailed assessment of damage to the population and physical resources due to blast, debris, and fires.

The results of the research were a series of reports on aspects of the physical and institutional infrastructure in the aftermath of the hypothetical disasters in each of the cities. Included among the topical reports were studies on individual support industries--natural gas,

---

*The UNCLEX-73 scenarios were hypothesized nuclear attacks developed to provide consistent scenarios for several studies of the postattack environment. The MIKE scenario emphasized military targets, while the CHARLIE scenario emphasized civilian targets. Under the latter scenario, a total of 6,000 megatons were delivered on population, military support industry, transportation industry, manufacturing industry, government centers, nuclear retaliatory capability, and military command and control centers.

**A detailed overview of the Five City Study is provided in Kerr, Harker, and Rockett (1967).

petroleum, electricity, water and sewerage, and radio and television broadcasting--and studies on social and managerial aspects of the individual communities in crisis. However, the discussion of the Five City results in this chapter will be limited to studies on the supporting utilities--electricity, natural gas, and petroleum distribution.

5.2. THE ALUMINUM INDUSTRY

Tate and Billheimer (1967) investigated problems associated with rapidly shutting down the aluminum industry in the event of international hostilities preceding a nuclear attack. The study was an extension of research undertaken by McFadden and Bigelow (1966) to examine the extent of damage caused by a rapid shutdown of critical industries. In the McFadden and Bigelow study, industries were ranked on the basis of their vulnerability to rapid shutdown of production. Four industries were identified as the most vulnerable--petroleum refining and petrochemicals, steel, aluminum, and explosives. McFadden and Bigelow examined the petroleum refining and steel industries in detail, while Tate and Billheimer studied the aluminum industry.

In the aluminum industry study, the authors conducted a detailed process analysis of the time needed for shutdown in various components of the vertically integrated production process to ensure minimal damage and restart times. Alumina refineries, primary aluminum smelters, aluminum fabrication plants, and secondary aluminum smelters were included in the study. Also, problems associated with the potential unavailability of electricity was examined. They concentrated their efforts on alumina refineries and primary aluminum smelters. The analysis was further limited to situations in which the facilities did not incur blast or fire damage but were shutdown to ensure that personnel were evacuated and safeguarded from radioactive fallout.

For the alumina refinery component, the operation can be terminated by cutting off electrical power. However, any shutdown that occurs within a 48-hour period necessitates repairs before startup. Damage and consequent repair efforts are contingent on the amount of time allowed for shutdown. For the aluminum smelter, the degree of damage is related to the length of time in which the facility was shut down, irrespective of the time allowed for shutdown. However, the extent of damage is also related to the time allowed for shutdown. For both alumina refineries and smelters, a shutdown with no advance preparation necessitates a minimum of two months to repair and restart and an orderly shutdown requires at least a 48-hour warning period.

Based on these analyses and the fact that technological advances will not change the characteristics of shutting down aluminum refineries and smelters in the foreseeable future, the authors concluded:

> The most practical way of meeting postattack aluimnum demands appears to be to: (1) rely largely on national stockpiles of aluminum in the immediate postattack period, (2) arrange for a phased startup of smelters and alumina refineries within specific regions, and (3) arrange for an equitable distribution

> of alumina inventories within specific regions that will fit the phased startup of refineries and smelters. (Tate and Billheimer, 1967, p. 6).

As part of a larger study on national survivability, Ellery Block et al. (1977) developed an approach to evaluating individual industries to determine which industrial sectors in the U.S. economy are the "most valuable to defend." The value of an industrial sector is determined on the basis of its ability to be substituted for. That is, industries that produce output which can easily be substituted for are considered less valuable than industries which cannot. The aluminum industry was initially selected for examination because of its importance in both defense and civilian applications.

The approach used by the authors was to examine in detail the vertically integrated operations of the aluminum industry to determine if there were any potential bottlenecks in aluminum production. The integrated operations included the alumina refining process, the smelting process, and fabrication processes.

A number of illuminating conclusions were drawn from the analysis with respect to the vulnerability of the U.S. aluminum industry, reliance on foreign supplies of aluminum, and modeling the aluminum industry. First, with respect to the U.S. aluminum industry, the authors concluded:

> . . . aluminum production can easily be interrupted, but it is difficult to destroy unless targeted directly. Furthermore, ... although the number of essentials to rebuilding a destroyed industry may be relatively large, many of those same essentials are needed by entire groups of related industries (and some unrelated ones as well). (Block et al., 1977, p. 102).

The authors pointed out that the four major problems in the industry are reliance on foreign sources of bauxite, reliance on the domestic transportation system for sources of bauxite supply, and reliance on significant amounts of water and electricity.

Second, the authors were concerned about the increasing tendency of foreign bauxite producers to integrate downstream in the production of aluminum. Although this may be a possible advantage because many sources of bauxite are in third world countries not likely to be engaged in nuclear conflict, the potential exists for reluctance on the part of these countries to ship to the United States after a nuclear conflict.

Third, after reviewing a disaggregated input-output table consisting of 367 sectors to determine potential bottlenecks in the supply of inputs to the aluminum industry, the authors concluded:

> . . . reliance on input-output coefficients is misleading for anything but final demand of highly aggregated sectors. (Block et al., 1977, p. 110).

The authors based this conclusion on the lack of detail on required supplies for the aluminum industry and, therefore, the meaninglessness of the use of the table for analysis.

5.3. THE CHEMICAL INDUSTRY

Foget, Van Horn, and Staackman (1968) evaluated standard industrial classification (SIC) code 281--the basic chemical industry--to estimate probable damage to the industry under various attack scenarios and repair requirements. The authors considered both primary and secondary weapons' effects. Estimation of repair efforts was based on restoring the 281 SIC code to 90 percent of its preattack capacity. Within the 281 SIC code category, the authors selected alkalies and chlorine (SIC 2812), industrial gases (2813), organic chemicals (2818), and inorganic chemicals (2819) for detailed analysis. Their approach was to identify processes common to production in the subindustries, to estimate physical damage to facilities under a number of different attack scenarios, and to estimate repairs required for operation of the damaged facilties.

The conclusions of the study were quite grim. Both for maximum repair efforts under the most severe attacks and lighter repair efforts, the authors concluded:

> This (maximum) repair effort corresponds to about five times the labor effort expended annually for new construction in the basic chemical industry group (for the year 1965) . . . However, even a selective limited repair effort would be likely to encounter constraints and shortages of a long-term nature. (Foget, Van Horn, and Staackman, 1968, p. 114).

In part, the authors based their conclusions on the unavailability of skilled labor in the postattack period and the susceptibility of certain components of the chemical industry to damage even from low attack levels. Moreover, the authors cautioned that the vulnerability of the industry would probably increase in the future because of increased reliance on automated control systems and their relative "softness" in response to attack.

5.4. THE CONSTRUCTION INDUSTRY

One of the most important industries in postattack recovery is the construction industry. A viable construction industry is necessary in the short term for rebuilding the physical infrastructure of the economy--roads, bridges, support industries--and in the longer term for restoring buildings and the like. Van Horn (1972) examined three interrelated aspects of the industry: (1) the effects of attack on the operation of the industry; (2) the types of demands the industry will potentially have to satisfy in a postattack environment; and (3) how the industry can be organized to meet those demands.

With respect to the effects of attack and the ability of the construction industry to satisfy postattack demand, Van Horn assumed two

different attack scenarios--a light attack in which 90 percent of the population and 80 percent of installed construction were estimated to survive, and a heavy attack in which the respective survival percentages for population and installed construction were estimated to be 65 and 40 percent, respectively. By assuming austerity factors for various types of construction activities, Van Horn concluded that the construction industry would have enough reserve capacity to resume construction even in non-critical industries in the aftermath of the light attack scenario. However, in the aftermath of the heavy attack scenario, Van Horn concluded that there would be significant deficiencies in the capability of the industry across different types of construction activity. For example, Van Horn estimated that it would take nearly three years to restore industry to a minimally acceptable level, where that level is reduced from preattack levels by an assumed postattack austerity factor. Moreover, the time required for restoration of military facilities and railroads would be 10.35 years and 8.00 years, respectively.

Recognizing that nationally aggregated analyses tend to distort recovery prospects, Van Horn examined construction activities in the San Francisco-Oakland area in a postattack environment. He assumed a one-megaton, nighttime airburst in the area and examined both short- and long-term construction efforts. For lightly damaged (windows and roofing, as examples) and moderately damaged (walls, for example) items, Van Horn found that the required resources for short-term repair were available in the area and the time required for repair efforts was generally well under a year. However, for heavily damaged facilities significantly longer time periods would be required. For industrial facilities, for example, Van Horn estimated that it would take nearly three years for restoration.

Van Horn argued that one of the most critical elements for recovery in the construction industry would be the establishment of a public command function to direct construction activities. The U.S. Army Corps of Engineers was advocated as a candidate to perform this function.

5.5. THE DRUG/ANTIBIOTIC INDUSTRY

Staachman, Van Horn, and Foget (1970) studied problems associated with the manufacture of four drugs considered crucial to lifesaving activities in the postattack period: (1) penicillin; (2) sulfa drugs; (3) injectable sodium chloride; and (4) immunization agents. The production of these drugs was selected from among a number of other drugs classified under SIC code 283. The procedure used for the analysis was to impose a range of hypothetical attacks on the industry and then estimate the level of repair necessary to resume production. In addition, the authors estimated whether potential postattack demand for the drugs could be satisfied by the available supply.

With respect to damage and repair efforts associated with the hypothetical attacks, the authors concluded in part:

> . . . it appears that the drug industry could be affected more severely than most industries by either a population or an in-

> dustrial type attack, but that it has more recuperative capacity. (Staackman, Van Horn, and Foget, 1970, p. 10-1).

The authors attributed the recuperative capacity of the industry largely to the relatively small capacity of the industry and the fact that the equipment used in producing the drugs is also used in other industries. However, the authors cautioned that the most significant vulnerable aspect of the industry is skilled labor. Moreover, the authors maintained that supplies of lifesaving drugs will be available in both the short term and long term. For the short term, restrictions on the use of drugs to lifesaving activities will ensure an adequate supply, while the relative ease in restoring the industry will ensure adequate supplies in the long term.

In a later study of antibiotics production in the postattack recovery effort, Bull (1971) examined the extent to which other manufacturing processes could meet the antibiotics production requirements in the postattack economy. Bull concluded that aerobic fermentation plants, producing such products as steroid hormones, yeasts, and vitamins, could be converted to the production of antibiotics. It was estimated that these plants could produce four and one-half times the output of the antibiotics plants themselves. Also, both changing the mix of products normally produced at antibiotics plants and eliminating purification and decolorization could also significantly increase the production of antibiotics.

5.6. THE ELECTRIC POWER INDUSTRY

Fernald et al. (1963) analyzed the vulnerability of the electric utility system to nuclear attack and the repair efforts required to restore the system. While the authors analyzed the effects of an attack on the entire domestic electric system, their detailed analysis of physical facilities and repair efforts was confined to the power system of the Tennessee Valley Authority (TVA). As a point of departure, the authors used the electric power problems encountered in Japan during World War II as an analogy to the problems that the U.S. power system could experience after a nuclear attack.

After reviewing the effects of the bombing raids on Japan in the spring of 1945 and the subsequent use of atomic bombs at Hiroshima and Nagasaki, the authors concluded:

> If the analogy of war destruction in Japan and the thermonuclear damage potential in the United States is at all valid, by extension or otherwise, electric power appears to be the key to all post-attack recovery considerations. (Fernald et al., 1963a, pp. 2-8, 2-9).

In their analysis of the vulnerability of the domestic electric power industry, the authors evaluated the operation of the total system and the vulnerability of components of the system to nuclear weapons' effects. Their application of this procedure to portions of TVA's electric power system led to the following conclusion:

> In general, the vulnerability studies indicate that the critical blast-damage levels for the hydroelectric facilities would be higher than those for the steam plant. Similarly, fallout hazards would be less serious at the hydroelectric plant than at the steam plant. Thermal radiation is not a major structural factor at any of the plants under consideration. The plant studies agree that production at most facilities would be interrupted by flying glass at blast overpressures within the range of 0.1 to 1.0 psi. (Fernald et al., 1963a, p. 1-2).

Doll, Borgeson, and Towle (1966) developed three approaches to estimate the ability of the electric power system to meet potential demand in the aftermath of a nuclear attack. The most sophisticated approach was a linear program of the industry, incorporating supply-side and demand-side activities. Demand for electric power was exogenous in the modeling system. Supply components included generating plants, transmission lines, and power substations. Data on capacities of each of these components were included in the system. The system was solved on the basis of minimizing shortages in the power system. Various attack scenarios could be simulated with the system by exogenously changing the values of supply- and demand-side parameters.

The other two methodologies developed by the authors were relatively nonrigorous. The first method involved coding electric system and nuclear weapons' effects attack data on key punch cards at the county level. The cards are then sorted and aggregated to both determine the number of counties experiencing similar effects of the attack and compare the effects of different attacks. The other nonrigorous method was a map exercise in which all generating units, substations, and transmission lines are coded and weapon damage radii from a hypothetical attack on the power system are used to determine damaged generating capacity, isolated generating capacity, and deliverable power. Each of these three methodologies was demonstrated and compared for the Tennessee Valley Authority's power grid.

Van Horn, Boyd, and Foget (1967) studied the vulnerability of a typical urban electric utility system and compared it with the vulnerability of a natural gas system.* The authors concluded that electric power systems are more vulnerable than natural gas systems:

> Electric utilities, on the other hand, are complex in design and operation, most critical elements are aboveground, major damage occurs in the 5 to 12-psi range, and repair effort is massive (predictions for the typical city are 284,000 man-days at 9-psi). (Van Horn, Boyd, and Foget, 1967, p. 8-1).

Foget and Van Horn (1969) analyzed the use of conventional and unconventional emergency power sources in the immediate aftermath of a nuclear attack. The authors quantified the inventory of emergency power sources in the country and delineated their operating characteristics to

---

*A description of the approach is provided below in the discussion of the natural gas industry.

determine the technical feasibility of using them in a postattack environment. Also, the demand for electric power was estimated along with the potential supply in four typical cities to determine the need for various types of power production. The authors then conducted two case studies of demand and supply using emergency power alternatives and compared the results of the studies with typical results from conventional power demand-supply studies.

The authors found that the two major sources of conventional emergency power were engine generator sets and industrial generating plants. The largest source of unconventional emergency power is "reversed" induction motors. Other unconventional sources were diesel electric drive ships and diesel electric locomotives, which were only located in specific geographical areas. The authors concluded that emergency power sources would be important in a postattack setting because they are a very valuable supplement to commercial power sources and, therefore, enhance marginal system capabilities. Also, based on the study of two cities, the authors concluded that it was technically possible to meet estimated postattack demand using emergency power sources.

While the results of the assessment of emergency power in a postattack environment by Foget and Van Horn were generally favorable, the authors cautioned against relying on emergency sources for all postattack power needs. The limiting factors included: (1) the sources are not available universally; (2) emergency sources require fuels which may not be available in the aftermath of an attack; (3) ventilation is required if they are used indoors; and (4) an extensive amount of preattack planning is required for their optimal use. With respect to the latter point, the authors pointed out that emergency power can be a viable alternative to commercial power only if local plans are developed by civil defense and industrial authorities for its use and if appropriate measures are taken in the crisis period preceding an attack.

Lambert (1976) estimated damage to various components of the electric power system induced by different overpressure levels of nuclear weapons. The purpose of the study was to identify critical elements of the electric power system, estimate potential damage, develop priorities for repair resource allocation, and provide estimates of the required repair effort. The approach used was to study prior research on the effects of attack on electric power systems to hold discussions with electric industry and civil defense personnel.

With respect to the vulnerability of electric power systems to nuclear attack, Lambert concluded that major damage to components of the network would occur even at low levels of overpressure. As the level of overpressure increases and very large-scale restoration efforts are required, a significant postattack problem would arise because of the specialized character of many of the replacement components. At a very low level of overpressure (one to two psi), electric power service would be disrupted for minor repairs. At three or four psi, extensive damage to electric distribution systems and failure of control systems in steam plants would necessitate large repair efforts. At an overpressure level of five or six psi, the majority of the system would experience extensive damage. With overpressure levels greater than eight psi, the

transmission and distribution systems would have to be totally rebuilt. At approximately ten psi, generating facilities would be damaged beyond repair, requiring total reconstruction.

To ameliorate potential problems with electric power in the aftermath of a nuclear attack, Lambert recommended that personnel involved in the operation of electric power systems should plan to estimate damage and isolate elements of the system that are especially vulnerable. Another recommendation was that utilities should consider "hardening" their systems against the effects of electromagnetic pulse. Finally, for control of individual systems, Lambert recommended standby emergency control measures:

> . . . since control components appear to be one of the most critical segments of an electric power system, it is recommended that in cases where considerable computer control and automation exist that operators be well-trained in converting and operating the system in the manual mode. (Lambert, 1976, p. 61).

As part of the Five City Study, Swart examined the operation of electric power distribution systems in the aftermath of hypothesized nuclear attacks in San Jose, California [Swart (1967)], Albuquerque, New Mexico [Swart (1969)], and Detroit, Michigan [Swart (1970)]. In each of the studies, the hypothesized attack was five megatons. Swart examined the ability of electric power systems to function in the three cities, with special emphasis placed on employees, facilities, communications, supplies, and equipment.

In the San Jose study, Swart concluded that, because of the nature of the assumed five-megaton airburst in the southern portion of San Francisco Bay, the downtown area of the city and two-thirds of the remainder of it would not suffer a loss of electric service. These areas would be subjected to less than 2.5 psi of overpressure. However, for the remainder of the city north and west of the city center, there would be widespread disruption of electric power because of overpressure levels of more than three psi. There would be further disruption of electric power in isolated parts of the city due to debris damage. In general, the survival of trained personnel, transportation facilities, and supplies would be more than adequate to sustain electric power service.

The attack scenario in the Albuquerque area was a five-megaton airburst above Kirtland Air Force Base. The results of the damage assessment showed that 95 percent of the users of electric power within the Albuquerque city limits would be unable to receive power because of damage to the customers' electric facilities. Nearly the entire city would be exposed to more than 2.5 psi of overpressure. Since most of the city would be devastated by the attack, reconstruction of the electric system would not be needed in the immediate postattack period. On the western edge of the city that would be exposed to less than two psi of overpressure, there would be debris damage caused by high winds, but enough of the electrical infrastructure would be viable after repairs.

In the Detroit study, the attack scenario was a five-megaton ground-level explosion in southwest Detroit. All of the distribution network within a radius of four miles of ground zero would be destroyed as a result of the explosion. Because of the nature of the assumed attack, only 10 percent of preattack load requirements for the metropolitan Detroit area would be required, and this could be met by the surviving generating stations. Trained personnel would survive in numbers sufficient to repair and operate the surviving portions of the system.

In a related study of utility systems' interrelationships in San Jose, Pickering (1969) investigated the interties between water supply, sewerage and drainage, electric power, gas, telephone, radio broadcasting, television, petroleum distribution, and local transportation. He identified the input requirements for each system, the points of interconnection, and the vulnerability of the interrelationships to the same five-megaton detonation that was hypothesized for the Five City Study. With respect to point inputs of one utility service to another, Pickering concluded that strong dependencies exist for electric power with both the water system and communications (telephone for radio and television). Moreover, critical intersystem relationships exist for sewerage and drainage and water, radio and television which require electricity on an area basis, and petroleum distribution which requires electric power for dispensing of fuel.

In another study of regional power systems, Lambert and Minor (1973a) developed a conceptual model to evaluate electric power systems, formulated a regional electric system model, and applied it to the Louisiana-southern Mississippi area. The model was a constrained network flow model, employing nodes, links, and an objective function. A node could be defined as a generating station--or an aggregation of generating stations--or a demand center. A link could be a high-voltage transmission line or a low-voltage distribution line. The objective function measured the effects of disruption on the electric power system and could be specified to measure any number of different requirements (manufacturing needs and evacuation requirements, as examples). In their application to the Louisiana-southern Mississippi region, the authors found that the loss of a single generating node with the exception of Orleans Parish did not have an effect on the system. Also, when one link was removed, there was no effect on the value of the objective function. With a combination of disruptions, however, there was a degradation in the value of the objective function.

5.7. THE NATURAL GAS INDUSTRY

Van Horn, Boyd, and Foget (1967) evaluated the effects of a nuclear attack and the consequent repair efforts for natural gas and electric utility systems in urban areas of the United States.* The approach used by the authors was to impose a hypothetical attack on an urban area, es-

---

*The present discussion will be devoted to their work on natural gas systems. The study of electric utility systems was discussed in the preceding section.

timate the damage to the underlying gas utility system, and develop a mathematical repair model to estimate the effort required to restore the system. In order to accomplish this, the authors developed a "typical" gas utility system, detailed the critical elements of the subsystems (the LPG storage tanks at a peak shave plant), and assigned criticality factors to each of the elements of the subsystem. The criticality factors--critical, semicritical, and noncritical--were an integral part of prioritizing repair efforts. Overpressure, dynamic pressure, missiles, and thermal pulse effects were calculated for a five-megaton low airburst. Repair efforts were estimated for each combination of two available labor skill levels--skilled labor and semiskilled labor--and three different assumed levels of repair--restoration of the original system, restoration to 90 percent of preattack design performance, and an expedient system in which output would be well below design capacity.

Although the authors recognized that there are a range of uncertainties in the postattack recovery effort (adequacy of parts, key shortages of skilled labor, possibility of system self-destruction), their conclusion was generally favorable:

> Gas utilities within metropolitan areas are relatively simple in design and operation; most critical elements are located underground, with the result that damage to a major portion of the system (i.e., pipelines) occurs only at very high overpressures. The repair effort for above-ground elements, which are damaged at overpressure levels of less than 12 psi is relatively small (predictions for the typical city are 40,000 man-days at the 9-psi level). (Van Horn, Boyd, and Foget, 1967, p. 8-1).

Stephens and Golasinski (1974) conducted an in-depth study of the total domestic natural gas system--reserves, physical facilities, physical interdependence, manpower, and markets--and the natural gas system in the southwest region of the country, encompassing Louisiana and parts of Mississippi. Their prognosis on the vulnerability of the system was grim. They concluded that there would be serious problems with the volatility of natural gas, the effects of electromagnetic pulse on computer systems that control the industry, power surges, and the transmission system. Although the authors acknowledged that transmission lines could survive a high-altitude explosion, they cautioned that a ground blast could separate the line.

The author's in-depth analysis of the Louisiana-southern Mississippi region provided even more ominous results. Special problems in that region are associated with repair efforts in swampy areas and the possibility of flooding of the city of New Orleans. The authors concluded:

> By seriously damaging the natural gas equipment of southern Louisiana, it would be possible to cut off a major supply of energy to eastern U.S. There is not enough heavy repair equipment or supplies available to make a large number of major repairs. Down time should be considered in terms of months or years. (Stephens and Golasinski, 1974, p. 98).

The authors also concluded that another serious problem is the possibility of explosions and fires and the lack of planning to deal with them:

> An attack on the system by either conventional or nuclear weapons is certain to cause fires and explosions of a size to be totally beyond the bounds of control. It is considered that most emergency planning does not take into account the possible magnitude of a series of major gas or oil fires. (Stephens and Golasinski, 1974, p. 98).

As part of the Five City Study, Richford and Davis analyzed the effects of nuclear attack on the local natural gas utilities in San Jose, California [Richford and Davis (1967)], Albuquerque, New Mexico [Richford and Davis (1968)], and Detroit, Michigan [Richford and Davis (1971)] and, in addition, described the functioning of the systems and enumerated the physical facilities that comprise them.

The authors found that a hypothesized five-megaton airburst directed at Moffett Field near the southern end of San Francisco Bay would not affect the physical gas transmission and distribution system serving San Jose. Moreover, estimates of casualties indicated that there would be no serious shortages of skilled workers to operate the system. Even though the system would not experience severe physical destruction, the authors also concluded that a portion of the system west of the city would be shut down because of structural damage to residences and other establishments that would experience gas leakages.

Again, in Albuquerque after a five-megaton airburst, the authors concluded that the functioning of the natural gas system would not be hampered by the hypothetical attack, but a small amount of supporting facilities would be destroyed (such as office equipment and telephone systems), requiring that the system be operated in an atypical manner. As with the San Jose study, the authors concluded that there would be enough skilled personnel surviving the attack to operate the system and, because of damage to 52 square miles of residences and buildings, a significant part of the system would be shut down because of gas leakages. The shutdown would affect 48,400 of the 77,400 preattack customers in the Albuquerque area. However, because of limited damage to the gas distribution system in the area that would be shut down, repair of the system in that area could be accomplished with a nominal effort.

The impact on the Detroit gas utility system would be a little more severe under the hypothesized five-megaton surface burst scenario than San Jose and Albuquerque. The distribution system serving more than 86 percent of the preattack number of customers would be shut down in a 227-square-mile area. Primary damage would be to buildings and the contents of regulating stations and storehouses. However, requisite resources for repair--personnel, communications, and vehicles--would survive in sufficient quantities to facilitate repair of the system. The amount of gas supplied to the Detroit system would be more than adequate because three of the four gas transmission systems serving the area would not be damaged by the blast.

5.8. THE PETROLEUM INDUSTRY

The U.S. petroleum industry is divided into (1) acquisition of crude petroleum--which includes crude oil importation, exploration, and production; (2) transportation of crude oil; (3) refining of crude oil; (4) transportation of refined petroleum products; and (5) distribution/marketing of products. Because of the geographical concentration of resources in this chain--especially crude oil acquisition and refining--and the importance of end-use products as inputs into other processes, a relatively small countervalue attack on the United States could seriously disrupt both the petroleum industry and economic recovery efforts. Therefore, a number of studies have been conducted to determine the industry's vulnerability in general, the vulnerability of petroleum refineries and crude oil and products pipelines, and expedient measures and damage minimization efforts that could be undertaken in both the preattack and postattack periods to mitigate the effects of an attack. A number of studies have also been conducted on regional petroleum systems, the most prominent of which are local petroleum distribution systems as part of the Five City Study.

As noted in the introduction of this chapter, McFadden and Bigelow (1966) examined the vulnerability of petroleum and petrochemical refining to a rapid shutdown of operations. The authors identified major processing units in refining and determine their interdependence on each other and supporting utilities. Existing emergency procedures were examined and the consequences of emergency shutdown were determined on the basis of published literature and discussions with industry personnel. The authors concluded:

> Shutdown of refineries under normal conditions may require 24 hours or more. Although refineries have been shut down rapidly in emergencies, such shutdowns are dangerous and may lead to considerable damage of equipment. The extent of this damage will depend on the size of the refinery and the effectiveness of shutdown procedures used. The time required to repair shutdown damage after a nuclear attack may range from a week for a small refinery, to several months for a very large refinery. Abandoning a refinery without shutdown is almost certain to result in a total loss. (McFadden and Bigelow, 1966, p. 4).

Thayer and Shaner (1960) undertook a study of the capability of the domestic petroleum industry to produce and transport gasolines and distillates in the aftermath of five hypothesized attack scenarios. The scenarios included (1) a counterforce attack (400 megatons), (2) a combined counterforce/population attack (1500 megatons), (3) another larger counterforce attack (19,000 megatons), (4) another larger combined counterforce/population attack (23,000 megatons), and (5) a combined counterforce/petroleum refinery attack (1,344 megatons), designed to destroy military targets and crude oil refineries. The authors conducted their analysis at two levels. A threshold level of recovery was considered in which gasoline and distillate needs were analyzed to determine sufficiency to commence recovery. The needs included food production; rail transportation of food, fuel, and the population; decontamination;

police patrols; and the rescue of injured survivors. A full economy recovery was also analyzed in which fuel supplies were analyzed for sufficiency to provide the same per-capita fuel consumption as the preattack period. Additionally, the authors examined the ability of the products pipeline transport system to function in the immediate aftermath of shelter egression and after a period of time in which minor repairs were made to the system.

For the four hypothesized attacks excluding the attacks on petroleum refineries, the postattack economy would be able to meet both threshold requirements and full economy requirements. In the aftermath of all five attacks, the economy would be able to meet threshold requirements. For the combination counterforce/refinery attack scenario, gasoline and distillates would not be available in sufficient quantities for a full economy recovery. For the refined petroleum products pipeline system, more than 75 percent of capacity would survive the attacks.

Stephens (1973) conducted a detailed study of the domestic petroleum industry. The study consisted of three parts. First, he provided a comprehensive overview of the entire domestic industry. Second, because of the concentration of the upstream segments of the industry in the southwest, he discussed the features of the industry in the state of Louisiana and surrounding areas. Finally, he discussed some of the most vulnerable features of the system. Stephens ranked components of the petroleum system on the basis of their vulnerability. The most vulnerable components include dependence on outside sources of electric power; the operation and control of pipelines because of their reliance on computer control and electric control lines; terminal areas; movements of barges and tankers; refineries; communications in general; repair parts; and oil production operations.

Fernald et al. (1965b) conducted a study of the vulnerability of the domestic petroleum industry to nuclear attack under various hypothesized attack scenarios. Since petroleum refineries are much more vulnerable than other portions of the industry, the authors expended the largest amount of effort on them. To provide a detailed assessment of probable damage and likley repair efforts in the aftermath of an attack, the authors examined three refineries located in Louisiana, Mississippi, and Indiana.

The primary conclusions of the study were that any refinery located within 10 miles of a one-megaton burst will experience severe damage, requiring forced shutdown for several months. Also, 163 weapons could substantially damage all refineries. Because of the geographical concentration of petroleum refining in the United States, one weapon could seriously damage 10 percent of all refining capacity, three weapons could seriously damage 25 percent of the total, and nine weapons could seriously damage more than one-half of capacity.

Based on their detailed analysis of three refineries, the authors also concluded that the most vulnerable components of a refinery complex are the control house and the cooling towers. However, adequate warning to shut down a refinery--in a period of rapidly rising international

tension, for example--could make a significant difference in the level and extent of damage.

Walker (1969) estimated the production capability and repair efforts needed in the domestic petroleum industry after blast damage from overpressure levels of 0.5, 1, 5, and 10 psi. The purpose of the study was to ascertain the benefits that would accrue to the repair of refineries, given knowledge of a specific refinery that was damaged and the overpressure level it was subjected to. He narrowed the 267 refineries in existence at the time to six broad categories. He represented crude oil by six major types, refining processes by 16, equipment by 25 types, and products by seven. The primary conclusions of the study were that at 0.3 to 0.5 psi of overpressure a refinery can produce proportionate amounts of output but at only 70 percent of capacity. At psi levels greater than 1.0, the refinery must be temporarily closed, but can be reinstated to 50 percent of original capacity with minor repairs to process controls. At 1.5 psi and above, a refinery would have to be totally shut down.

Stephens (1970) discussed the vulnerability of petroleum refineries to natural disasters and nuclear weapons' effects. One of the purposes of the study was to isolate specific vulnerable components of refineries so that refinery owners would have a basis on which to make hardening decisions. The discussion addressed the nature and magnitude of a range of blast or natural disaster effects and possible ameliorating measures that could be taken to "harden" a refinery from these effects. Stephens concluded that the vulnerability of refineries to nuclear weapons' effects or natural hazards is increasing because of (1) the increasing geographical concentration of the industry in regions especially susceptible to natural hazards; (2) the dependence of the industry on purchased electric power; (3) the increasing computerization of the industry, and its sensitivity to the effects of blast or natural hazards; (4) the increasing tendency not to hold critical repair parts in inventory; and (5) the concentration of crude supply in a few areas, using larger storage tanks and supertankers which are especially vulnerable to mass fires.

Miller and Stratton (1980) examined the operations of refineries in the postattack environment. Their study was focused on (a) a damage description of a "typical" refinery, consisting of 32 major components with 75,000 barrels-per-day of throughput; (b) estimation of repair efforts for these refineries; and (c) development of expedient techniques to produce diesel fuel that would be required in various phases of the recovery effort. Relying on prior studies which concluded that a refinery would be totally inoperative if an attack occurred while the refinery was in operation, the authors assumed that the refinery was shut down prior to the attack in their analysis.

Perhaps the most important result of the study was development of an Expedient Crude Oil Unit (ECOU) which would preclude the need to reconstruct or repair a refinery to produce diesel fuel. The authors concluded:

> The advantage of the ECOU . . . is that, for less than one-tenth of the effort required to restore a heavily damaged refinery to productive status, diesel fuel production could be restored. In addition, the delay time to production after attack would be reduced from about 1 year to about 2.5 months. Finally, the material resources that need to be stockpiled for constructing the ECOU would be much less than those required for reconstructing the whole refinery. (Miller and Stratton, 1980, p. 88).

As part of the Five City Study, Checchi and Company undertook studies of the local petroleum distribution systems in three localities: San Jose, California [Lerner, Grigsby, and Johnson (1967)], Albuquerque, New Mexico [Grigsby, Manly, Boesman, and Johnson (1968)], and Detroit, Michigan [Boesman, Grigsby, and Manly (1970)]. The approach used in all of the studies was to impose a hypothetical five-megaton attack near the cities and analyze the effects of the attack on (1) inventories of gasoline, diesel fuel, liquefied petroleum gas, and other petroleum products; (2) the physical facilities used to store and distribute those products; and (3) the labor skills required for operation of the distribution systems. A detailed, facility-by-facility analysis of the attack's effects was conducted.

In the San Jose study, the authors concluded that flexible management of surviving physical facilities and inventories of products would be crucial for recovery:

> This comparative analysis of the attack effects on personnel and facilities within the local petroleum distribution system suggests that each class of facilties can be operated if wise decisions are made regarding which facilities are to remain in operation and if an optimum allocation of strategic personnel is made. (Lerner, Grigsby, and Johnson, 1967, p. 191).

Although the city of Albuquerque would confront a different array of problems, the conclusion was similar:

> A comparative analysis of the attack effects on personnel and facilities within the local petroleum distribution system suggests that each class of facilities can be operated if wise decisions are made regarding which facilities are to remain in operation and if an optimum allocation of strategic personnel is made. (Grigsby, Manly, Boesman, and Johnson, 1968, p. 153).

In recognition of the problems associated with viewing a local petroleum distribution system in isolation, Manly, Lerner, and Grigsby (1970) developed a framework for analyzing the vulnerability of a national petroleum distribution system. In the national system context, some of the problems identified as having an impact on local distribution systems included flow of products into and out of the local system, the relationship of the local system to the economy of which it is a part, and constraints manifested in the system in the form of information and a medium of exchange.

The conceptual model of petroleum distribution vulnerability developed by the authors was based on the circular relationship between a local economy or subeconomy and the national economy. Succinctly, the authors developed a system that contained a relationship of inputs, outputs, control, processes, and adjustments. Analysis of the vulnerability of a local system should systematically consider the vulnerability of each of the components of the system. Besides a simple assessment of inventories, physical facilities, and personnel, the systemic analysis would include analysis of communications, transportation services, monetary considerations, loss of input inventories, loss of output inventories, loss of key supporting service inputs (electricity and water, for example), and demand effects.

The U.S. General Accounting Office (1979) evaluated the vulnerability of both the crude oil and refined petroleum products pipeline system to a range of different disruptions--sabotage, human error, and natural phenomena. Based on examining the pipeline system which accounted for approximately 75 percent of crude oil transported to refineries and more than 33 percent of refined products shipped from refineries to consumption centers at the time of writing, the report concluded in part:

> In the event key facilities on just a few important pipeline systems were damaged, domestic shipments could be greatly reduced. The United States could suffer an energy shortage exceeding that caused by the 1973 Arab oil embargo. GAO found that the petroleum industry is not adequately emphasizing the physical security of some key pipeline systems. And neither industry nor the Federal Government has plans for dealing with the critical impact of petroleum shortages should key pipelines become seriously damaged and disruptions occur. (U.S. General Accounting Office, 1979, p. i).

In part, the authors of the study based their conclusion on the observation that two crude petroleum pipelines--the Trans-Alaska Pipeline System and the Capline system--and one refined products system (the Colonial system) accounted for 15 percent of crude deliveries to refineries and 9 percent of total refined product consumption, respectively.

Goen, Bothun, and Walker (1970) examined the vulnerability of refined petroleum products pipelines to nuclear attack and assessed alternative means of transportation by rail and truck as part of a larger study of potential vulnerabilities in the U.S. economy. Since pipelines are buried, they are generally immune to blast damage. However, storage tanks would be severely damaged at a blast overpressure level of three or four psi. Pump stations along the pipeline route could be irreparably damaged at overpressure levels of 10 psi. The authors estimated that ten well-placed "hits" could put the three largest petroleum products pipelines out of service--three on the Colonial system, which extends from the Gulf coast to the northeastern port area; two on the Plantation system, which parallels the Colonial up through Virginia, and five on the Texas Eastern system. At the time of writing, these three product pipeline systems accounted for 63 percent of the total barrel-miles of refined products transported by pipeline in the United States. The authors also estimated that a total of 126 "hits" could severely

damage the "major portion" of U.S. product pipeline transport. The authors concluded:

> This number of hits would put the major pipeline transportation and distribution of products out of service by isolating general areas served by pipelines down to and including 6-inch-diameter size. This essentially halts the required supply of products from the refining areas to the agricultural and industrial areas. It would not completely eliminate use of smaller lines within each area. (Goen, Bothun, and Walker, 1970, p. 65).

With respect to alternate sources of transportation for refined products, the authors analyzed the feasibility of rail transport (tank cars) and tank trucks to meet the petroleum tr port requirements. Based on their examination of critical shortage areas--tank cars used for transport from the Gulf coast to the East coast and Midwest, for example--and expected surviving rail and truck resources, the authors concluded that

> . . . alternative means of delivery of petroleum products, after loss of the pipelines, appear to be potentially adequate. However, the reorganization of the transportation and distribution system would be a formidable task. (Goen, Bothun, and Walker, 1970, p. 70).

5.9. THE PROCESS CONTROL INDUSTRY

Van Horn and Crain (1975) investigated the effects of nuclear attack on the production of instrumentation devices under SIC code 3821--mechanical measuring and controlling instruments.* Instrumentation was emphasized because of its importance as an input to industries critical to a postattack recovery effort. For example, three important industries--chemicals and allied products, petroleum refining and related industries, and electric utilities--accounted for 45 percent of the use of instrumentation products in the United States at the time of writing. The authors assessed the effects of a hypothetical attack by examining blast, electromagnetic pulse and weathering effects from a five-megaton low air burst. The effects of the hypothesized attack were estimated for instrumentation manufacturers and instrumentation users.

For instrumentation manufacturers, the authors concluded that manufacturers of pneumatic instrumentation devices will not be as severely affected as those that manufacture electronic instrumentation products. The reason was that the former are almost totally self-reliant in a manufacturing complex, while the latter manufacturers rely extensively on outside suppliers for critical inputs. The most significant inputs to

---

*The scope of their research encompassed production in four other SIC categories relating to instrumentation. However, they focused their efforts on SIC 3821 because of its relative importance as an input into other manufacturing processes.

the electronic instrumentation industry are other electronic components such as resistors and transistors which were principally produced in two regions of the country--northern California and the Boston corridor--that are themselves vulnerable to a countervalue attack. The authors conjectured that the support of the electronics industry in the production of electronic instrumentation

> . . . might present a very real constraint and prevent the reinitiation of instrumentation fabrication for a period of six months or longer after attack. (Van Horn and Crain, 1975, p. 8-4).

The prognosis is even more discouraging for instrumentation users. While pneumatic instrumention is less vulnerable to attack than electronic instrumentation devices, the growth of technology has spurred adoption of the latter. For this reason, one of the major recommendations of the study was to update it:

> Because of the rapid adoption of sophisticated, but very sensitive, electronic control systems by critical industries, consideration should be given to updating the present study within five years to determine if serious deterioration of instrumentation availability following nuclear attack might have occured. (Van Horn and Crain, 1975, p. 6).

5.10. THE RUBBER INDUSTRY

Block et al. (1979) examined both consumption and production of essential rubber products after a full-scale nuclear war. Included in the study were the identification of rubber products essential for national survival, estimates of early postattack demand for these products, identification of bottlenecks in the production of essential products, the vulnerability of production processes, and countermeasures to mitigate vulnerability of the industry. Analysis of consumption in the postattack period was limited to the most essential uses of tires (medium and large truck tires, off-the-road tires, and tires for agricultural use), hoses, and belts.

On the demand side, the authors concluded that the production of medium and large truck tires will be the most important activity in the industry in the early postattack survival phase because these tires use proportionately more rubber and their lives will be shortened under postattack road conditions. The demand for hoses will be important later on in the recovery effort. The demand for belts will be important in the early survival and recovery phases because of their use in such important activities as coal mining, industrial rebuilding, and mechanical power transmission.

For the production of tires, the authors concluded that the availability of resorcinol formaldehyde used to coat tire cords and plies is a potentially significant bottleneck. They based their conclusion on the observation that only one U.S. manufacturer produces the product and the facilities of that manufacturer are themselves vulnerable to attack.

For the production of rubber itself, the authors pointed out that steam is the primary utility service used in production and steam boilers are vulnerable to attack. Electricity is the second most important input used to drive high-horsepower electric motors. The electric motors themselves have long lead-times (28 to 32 months) for replacement. Another aspect of the rubber production process that is especially susceptible to nuclear attack is the instrumentation and controls used in the production processes. Moreover, one of the primary inputs for rubber production is petroleum which is vulnerable and has no substitutes in the production process.

The authors acknowledged that some of the vulnerabilities associated with rubber production could potentially be mitigated by government stockpiles of natural imported rubber. They estimated that two-thirds of the early postattack demand for rubber could be supplied by stockpiles. However, they argued that these stockpiles are themselves vulnerable to attack because of their location--primarily on military depots--and their concentration--70 percent of the stockpiled supply was in five of fourteen stockpile locations at the time of writing.

5.11. THE STEEL INDUSTRY

Fernald et al. (1963b) examined both the effects of a shutdown caused by fallout radiation and structural damage resulting from blast overpressure in the steel industry. The authors studied a large steel complex in western Pennsylvania to identify bottlenecks in the flow of materials through an integrated process. Two major conclusions resulted from the analysis. First, the authors stressed the importance of access to electric power in the recovery effort--either generated internally or obtained from commercial sources. They argued that electric power supply should be the first priority in the recovery effort. Second, they emphasized the need for advance planning to mitigate the effects of attack:

> A most cogent factor in recovery is pre-attack preparation or shutdown which can preclude considerable damage when properly managed. (Fernald et al., 1963b, p. 1-1).

In general, the authors were positive in assessing the potential for recovery in a steel complex:

> It is not safe to assume that destruction connotes annihilation in a major industrial complex. Certainly, many physical structures can withstand blast damage, other than a direct hit, up to a fairly high level of overpressure. This is demonstrated at the steel mill. (Fernald et al., 1963b, p. 1-1).

McFadden and Bigelow (1966) examined the vulnerability of the steel industry to a rapid shutdown of operations. The approach used by the authors was to identify major processing units in steel production and determine their interdependence both on each other and supporting utilities. Existing emergency procedures were examined and the consequences

of emergency shutdown were determined, using the published literature and discussions with industry personnel. The authors concluded:

> Potential damage from the loss of services or from too rapid a shutdown could be as extensive as direct blast damage. Indeed, blast furnaces and coking ovens are subject to essentially complete destruction from explosions in the event of abandonment or improper shutdown. (McFadden and Bigelow, 1966, p. 5).

The authors estimated that it would take as long as several days to shut down a blast furnace and several hours for components such as steel convertors and mixers. An orderly shutdown of the industry requires trained operating crews, uninterrupted electric power, heating sources, and steam. The authors also concluded that the absence of any one of these supporting services could be as detrimental as the absence of all of them. Thus, the industry is particularly susceptible to large losses of productive capacity in the event of an attack that occurs without prior warning.

5.12. THE TRANSPORTATION INDUSTRIES

The purpose of this section is to review studies of the U.S. transportation system in the aftermath of hypothesized nuclear attacks. The domestic transportation system is composed of railroads, highway transport (cars, trucks, and buses), inland waterways, air, and pipelines. Studies of the pipeline network were addressed above in the sections on the petroleum and natural gas industries.

The majority of research on the transportation system in the aftermath of an attack was conducted in the 1960s at the Stanford Research Institute (SRI). The studies included five transport modes--railroads [Dixon, Haney, and Jones (1960) and Jones (1961)]; motor trucks [Bigelow and Dixon (1963)]; inland water transportation [Andrews and Dixon (1964)]; passenger and cargo air transportation [Crain (1965)]; and passenger transportation systems in general [Ross (1967)]--and an additional study on intermodal freight transportation [Dixon and Tebben (1967)] that draws upon the other studies. With the exception of the last study by Dixon and Tebben, the approach used in all of the studies was to segregate the transport system into a number of parts, construct data bases to characterize the decomposed system, impose a hypothetical nuclear attack on the systems, estimate damage to the system, and assess the viability of the damaged system.

In assessing prior research on the transportation network in a postattack environment, Hamberg (1969) summarized the problems associated with evaluating the viability of transportation networks in postattack environments:

> This lack of a clear understanding of the postattack society and its recuperation and recovery goals and schedules precludes a meaningful expression of the capability of the surviving transportation systems to meet the demands of the post-

> attack period because system capability is highly dependent not only on the amount, kind, and distribution of its resources, but also on <u>how</u> it is operated, <u>what</u> it must transport, <u>where</u> it must move the freight, and <u>when</u> it must move it. (Hamberg, 1969, p. 7).

Nevertheless, the studies do provide an indication of the severity of the transport problem in a postattack economy, even if it is under assumed conditions.

For the analysis of each of the five transport modes--railroads, motor freight, surface passenger traffic, air carriers, and domestic waterways, four hypothesized attacks were imposed. For the early 1960s, both counterforce (400 megatons) and counterforce/population (1500 megatons) attacks were hypothesized. Similarly, for attack levels presumed to be feasible in the late 1960s, a counterforce attack of 19,000 megatons and a combination counterforce/population attack of 23,000 megatons were hypothesized. The physical effects of the attacks were estimated using computer programs of the National Damage Assessment Center.

For railroads, Dixon, Haney, and Jones (1960) concluded that the effectiveness of the system will be a function of the method in which it is managed. This conclusion rests on the observation that substantial resources required for the operation of the railroad network would survive. Although no individual component of the railroad network would universally be a bottleneck, there would, however, be regional differences in the availability of certain components. Electric power could be a problem as it will in other industries. Classification yards and signalling systems are especially vulnerable to nonavailability of electric power.

In an extension of the railroad study, Jones (1961) examined the vulnerability of 12 important U.S. rail activity centers. In the earlier study, the U.S. rail transport system was characterized as a system of 37 nodes or rail activity centers, linked by the major lines of the 25 largest railroads existing at the time. The rail activity centers represented points of origin and termination of rail shipments. The twelve activity centers chosen for detailed examination reflect what the author believed to be the most important centers in the nation and those thought to experience problems representative of all activity centers in the aftermath of an attack. The 12 centers span the continental United States from the west to east coasts.

The attack scenario chosen for study was the early 1960s combined counterforce/population attack of 1500 megatons. To avoid the problems associated with guessing at the traffic mix at the rail activity centers, Jones selected food as the subject of analysis at the centers, because its postattack requirements can be estimated more accurately.

Jones concluded that physical facilities required for operation of all of the activity centers--yards and tracks, for example--would be available under the hypothesized attack. He noted, however, that many of the individual centers would confront special problems relating to the transport of food. For example, in Minneapolis and Kansas City, the

requirements for transporting food could place a restriction on the transport of other commodities needed in the recovery effort. In Los Angeles, the relative scarcity of rail lines could pose a significant problem. The northeast could experience severe problems because of the loss of through routes. One of the potential problems that Jones was concerned about was management of food transport, transport of other commodities, and transport using other modes, especially with the deaths of top-level management in the railroad industry. He concluded:

> . . . for the areas studied, food could be delivered by rail to within a few miles of nuclear attack survivors . . . The complexity of the local distribution of a single commodity demonstrates the need for careful organization and effective management of transport systems following a massive nuclear attack, for, in addition to meeting the emergency needs of survivors, transportation would be required to support a reconstruction program. (Jones, 1961, p. 11).

Bigelow and Dixon (1963) examined aspects of U.S. motor truck transportation, including personnel, roadways, vehicles, supplies, and facilities. The authors concluded that, given even the most serious hypothesized attack, a large portion of physical resouces would survive the attack. One of the most serious problems confronting the industry would be the loss of personnel due to fallout radiation. The authors estimated that, if adequate fallout shelters were provided for workers in the industry, 1.3 times as many workers would be available following the early 1960s counterforce/population attack. The corresponding figure for the late 1960s counterforce/population attack was 2.7. For the supply requirements of the industry such as spare parts and tires, the authors were concerned that the loss of manufacturing capacity for these items could prove to be a significant bottleneck within a few months following an attack.

Andrews and Dixon (1964) examined the vulnerability of four components of the U.S. domestic water system--personnel, vessels, terminals, and waterways. A number of features of this transport system make it relatively more vulnerable to attack than other industries. These features include the characteristics of the waterways <u>per se</u>, bridges that span waterways, dams and locks on the waterways, and the concentration of personnel in the industry. The authors concluded that the most vulnerable aspect of the inland waterway system to an attack with cities as targets is the system's "tree" network. That is, given a blockage at one point in the system, there is no way for vessels to circumvent that blockage. Related to this point is the fact that bridges, dams, and locks are highly vulnerable to an attack on population centers and their destruction poses a threat to closing down the transport network. Skilled personnel--longshoremen, management, and technical staff--in the industry are also highly vulnerable to an attack on population targets because of their relative concentration in a few major port cities. Similarly, because of their concentration, deep-water terminals are vulnerable to an attack on cities.

On the other hand, an attack with defense facilities as the primary targets would cause little damage to the inland waterway system. Be-

cause of water depth and waterway width, fallout would not pose a significant obstacle in postattack vessel movement. However, even with little physical damage in certain types of attacks and relative immunity to fallout radiation, the authors concluded that inland waterway transportation is of little use for population maintenance in the immediate recovery period because most of its capacity is devoted to bulk volume movements--petroleum products, for example--and conversion for use in transporting relief supplies could not be accomplished very easily.

Crain (1965) studied the air transportation system. The singlemost important conclusion of the study was that both commercial aircraft not in flight and support facilities for aircraft operations (maintenance facilities, spare parts) are located in large metropolitan areas which are especially vulnerable to population-related attacks. Aviation in general, however, is widely dispersed throughout the country and, therefore, is not as vulnerable to any type of attack. The problem with general aviation, however, is that lack of adequate planning could prove to be detrimental in an industry that is dispersed and diffuse. Coordination could pose a significant problem in postattack recovery.

Ross (1967) examined U.S. passenger transportation by all modes of transport. Included among the transportation modes considered were passenger trains, commuter rail, rail rapid transit, intercity and city buses, and private automobiles. The scope of the research included (1) developing an inventory of vehicles (automobiles, buses, and trains) and facilities (roads, streets, highways, and tracks), (2) examining capabilities of the system based on observed characteristics of the modes, and (3) discussing elements of the system that are most vulnerable to attack. Because of insufficient funds, a detailed damage assessment under various attack scenarios was not conducted as in the other SRI transportation studies. The vulnerability analysis was limited to passenger transportation vehicles because these physical facilities were discussed in the Dixon, Haney, and Jones (1960) rail study and the Bigelow and Dixon (1963) motor truck study.

With respect to the vulnerability of vehicles, Ross concluded:

> The vulnerability to damage by blast effects and thermal radiation does not appear to be significantly different for automobiles, buses, and rail passenger cars. The protection provided passengers from fallout radiation is significantly different for the different vehicles. This is particularly true if expedient shielding is provided. (Ross, 1967, p. 5).

The authors further pointed out that automobiles provide the least protection from fallout and rail passenger cars the best.

In addition to these six studies on five transport modes, Dixon and Tebben (1967) analyzed intermodal freight transport, drawing extensively from the six studies. The authors examined the problems associated with transferring transport loads from one vehicle to another and between a vehicle and a terminal for seven categories of goods--bulk liquids, bulk friables, heavy unit loads, palletized cargo, containerized cargo, loose cargo, and refrigerated cargo. To reduce the dimensions of the study,

the authors limited their analysis to the city of St. Louis. The focal point was to delineate the preattack movement of the seven classes of commodities and, given the destruction hypothesized in the attack scenarios, provide alternative transport of these commodities, both by different carrier modes and different routes.

Hall conducted studies of the local transportation systems in San Jose, California [Hall (1968)] and Albuquerque, New Mexico [Hall (1967)] as part of the Five City Study. The approach taken by Hall was similar to that taken in the earlier transportation studies at SRI. An inventory of physical facilities in the two cities was compiled and the capabilities of the transport system after the hypothesized attacks in each of the cities were estimated. The transport functions and facilities considered by Hall were freight movement by railroad and truck; local and suburban public passenger transportation by rail and motor vehicle; airports; private automobile travel; and warehousing. Waterborne commerce was considered only in San Jose because there are no navigable waterways in the Albuquerque area. The assessment of transport viability in both areas was based on the survival of traveled throughways, vehicles, facilities, supplies, and trained personnel.

In the San Jose area after a five-megaton airburst over Moffet field in the southern part of San Francisco Bay, Hall concluded that the survival of traveled ways, facilities, and personnel would be sufficient for the transport system to function, but the presence of debris would hamper the functioning of the former two. For vehicles, Hall concluded that railroad cars and motor vehicles would survive in sufficient quantities, but, because of their concentration, general aviation aircraft were more vulnerable. The most significant constraint on the functioning of the transport system would be the availability of fuel.

The conclusions for Albuquerque in the aftermath of a five-megaton airburst over Sandia base were similar except that, since aircraft are more dispersed in the area, they are less vulnerable and the required personnel to operate the system may not survive in required proportions.

In the review of transportation research conducted by Hamberg (1969), the author recommended further research on the vulnerability of both multimodal national transportation systems and regional systems. The first study was conducted by Hamberg and Hall (1970). They developed a framework for analyzing the vulnerability of the national transportation system. The second study was conducted by Hamberg (1971). He examined the vulnerability of the regional transportation network in the state of Louisiana and 13 counties in Mississippi.

Hamberg and Hall developed a methodology to evaluate the vulnerability of transportation systems. The approach included data collection; determination of capacity and capability of the system by transport mode; damage assessment; integration of modal systems into a total system; determination of requirements for the system; and evaluation of options to reduce vulnerability. In the second study, Hamberg developed data for the highway and rail transport modes in the Louisiana-southern Mississipi area.

In a later study at the University of New Orleans, Brite and Segal (1976) evaluated the transportation network of the Louisiana-southern Mississippi region which was the subject of Hamberg's 1971 study. Brite and Segal characterized a transportation network as a series of triads for each transportation mode. A triad consists of inputs, outputs, and thruputs. Inputs are the people or goods to be transported by class and location. Outputs are the transported goods by class and destination. Thruputs are the conduit which transforms inputs into outputs. They include vehicles, control facilities, terminals, and routes. Additionally, there are crossflow elements which are used in conjunction with thruputs to transform inputs into outputs. Those crossflow elements include fuel, personnel, and supplies. The authors demonstrated the use of their conceptual design in one experiment by computing criticalities using hypothetical data. Criticalities were defined as the ratio of requirements for transport to the capabilities of the system to transport them. In another experiment, the authors developed a systems model comprised of nodes, transport modes, and transport requirements at each node to simulate flows of goods.

Faucett (1976a, 1976b) examined existing transportation models to determine their compatibility with the needs of civil preparedness planning. His conclusion was that the models were constructed primarily for transportation development planning and, consequently, do not fit the needs of emergency planning. He concluded that efficient scheduling models were needed for aircraft passengers and cargo, intercity buses, the railroad network, the intermodal railroad/water network, and the pipeline network. He recommended development of an interregional input-output model that incorporates production and consumption by region as the best approach for handling interregional freight transport scheduling. He recommended a two-tier input-output model in which the first tier would represent regional activity and the second tier would reflect subregional activity.

6. INSTITUTIONAL INFRASTRUCTURE

6.1. INTRODUCTION AND SUMMARY

The purpose of this chapter is to review prior research on institutional aspects economic recovery in the aftermath of a disaster. After a summary of prior research, the discussion will turn to a more detailed examination of the contributions of individual studies. The chapter is divided into five areas: (1) economic organization and stabilization; (2) the monetary system; (3) the fiscal system; (4) damage compensation; and (5) a historical analogue--the reconstruction of Germany following World War II. Although there is a considerable degree of overlap among the first four sections, the discussion has been organized in this manner for reasons of expositional convenience. Also, the classification of topics makes no distinction for the severity of the disaster; that is, geographically localized disasters versus generalized disasters. However, the distinction is readily evident from the context of the research.

As was the case with studies of the physical infrastructure of the postdisaster economy, the majority of prior research on institutional issues has been focused on recovery from large-scale disasters resulting from a nuclear attack. The literature on institutional issues associated with localized disasters resulting from natural phenomena has emphasized damage compensation. Concisely, the majority of authors have argued that a comprehensive system of disaster insurance is much preferred to the present ad hoc approach of compensating for losses.

In contrast to prior research on the physical infrastructure in the aftermath of a nuclear attack, there have been relatively few substantive studies conducted on the institutional infrastructure in a postattack environment. The consequences of this gap in the literature for economic recovery have been underscored by contributing authors over the past three decades.

For example, Cavers (1955), writing in the early years of the nuclear age on institutional issues associated with nuclear war, concluded:

> . . . the problem (of nuclear attack) has been unfortunately conceived largely in terms of physical arrangements. Even the most far-reaching of our non-military defense planning efforts, Project East River, devoted virtually no attention to problems of legal and economic organization. Indeed, of its 263 recommendations, only one in my opinion fits into this category. . . (Cavers, 1955, p. 131).

Furthermore, in their comprehensive research on the vulnerability of the nation as an entity to nuclear attack, Dresch and Ellis (1966) stated:

> . . . some of the most important effects of a massive attack may not come from the direct effects on property and capacity

> but from the indirect effects on institutions and attitudes. (Dresch and Ellis, 1966, p. 11)

Moreover, in assessing research undertaken on the postattack economy, Dresch and Ellis concluded:

> Past studies of industrial and economic vulnerability have gone into detail in the analysis of surviving capacity, the requirements for repair, conversion, and reconstruction of capacity, the allocation of facilities and other resources, and the feasibility of meeting alternative schedules for economic support and recovery. <u>The attention devoted to institutional and organizational aspects of recovery management, however, has been hopelessly limited</u>. (Dresch and Ellis, 1966, p. 117) (Emphasis supplied).

Finally, writing more recently on prospects for recovery from nuclear attack, Greene, Stokley, and Christian (1979) concluded in part:

> The major unanswered questions deal with human behavior, social and political disorganization, and the restoration of a functioning economy--all questions not of physical resources, but of 'management.' (Greene, Stokley, and Christian, 1979, p. v).

In summary, almost without exception, published research on institutional issues associated with a postattack economy has been speculative or superficial, generally lacking an analytical basis. Although the most prominent institutional problems that are likely to arise in a postattack environment have been defined, there is a need for more rigorous analysis of management and control measures, monetary issues, a system of taxation, and war damage compensation.

Concisely, approaches to economic management and organization in a postattack environment can be bounded on one end by complete nationalization of all economic resources with total central control and, at the other extreme, by total reliance on the market mechanism to allocate surviving resources. A multitude of resource management approaches, characterized by various degrees of governmental intervention, lie within these bounds. The types of intervention include partial nationalization--the nationalization of food reserves, for example--and various degrees of intervention such as rationing, wage and price controls, allocation schemes, and government allotments.

The literature on economic organization and stabilization in the postattack economy has addressed the spectrum of control and stabilization possibilities. Winter (1968), for example, concluded that, without adequate budgetary allocations in the preattack planning period--to both formulate a detailed plan and ensure the protection of management resources to implement the plan in the postattack economy--the only viable function that the federal government can serve in the postattack economy would be to re-create the monetary system, property rights, and the legal system. In Winter's view, total nationalization of resources for a period of time in the aftermath of attack is appealing because a system

of "disaster socialism"--economic activity by government fiat--would make it unnecessary to immediately rebuild economic institutions. However, the inadequacy of budget appropriations eliminates this alternative from consideration.

Other contributors to the literature have also questioned the ability of the federal government to directly control all economic resources in the postattack period. The participants in Panel D of Project Harbor on postattack recovery [National Academy of Sciences (1963)] eliminated direct controls from consideration as a postattack management alternative because the U.S. system of resource allocation does not lend itself well to building expertise in central management of the economy. In their view, the information required to manage the economy is not centralized, but dispersed throughout the economic system.

Another critical factor in eliminating centralized control by the Federal government from consideration is the importance of resource allocation in the period immediately following an attack. Dresch (1964, 1965), for example, developed a detailed master scheduling system that could be used by the federal government in managing the postattack economy. The scheduling system would involved coordination between a centralized authority--the Recovery Production Agency--and regional recovery management agencies. However, Dresch (1968b) later abandoned this system because of its unwieldiness in the most critical period of recovery--the first two months immediately following an attack.

If centralized control is infeasible, the critical question then is what type of resource management system should be adopted in the postattack environment. Sobin (1970), for example, argued that, although centralized control has historically proved inefficient, reliance on a free market economy may be ill-advised because of the wild price fluctuations that will almost certainly result from the disproportionate destruction of resources. Several authors have addressed the pricing problem. Winter (1966), for example, argued that the federal government could provide price signals to a market-based postattack economy. The price signals could result from futures markets or some other innovative approach such as advisory prices or selective price guarantees.

Therefore, both total centralized control and total reliance on the market mechanism have not been viewed as viable solutions to the postattack management problem. The most common theme running through the literature is that reliance on the market mechanism, augmented by select government intervention, should be the basis for the Federal government's planning. However, many authors have argued that a general system of wage and price controls, rationing, and allocation which was used in the reconstruction of Germany after World War II should not be applied to a severely damaged economy. As discussed in the last section of this chapter, the policies of repressed inflation and commodity controls in Germany immediately after the war were counterproductive. Sustained economic growth occurred only after the system of wage and price controls, rationing, and allocation schemes were lifted.

A recurring theme in the literature is that the Federal government should restrict its activities to intervening in specific sectors of the

economy and rebuilding the economic institutional infrastructure. Good candidates for select intervention or control are supporting sectors--electricity, transportation, and natural gas, for example--because of their importance in the recovery effort. Economic institutional programs include creative use of monetary and fiscal policy.

Two potential institutional problem areas in a postattack economy requiring innovative solutions are excess purchasing power and a lack of funds for investment. In one scheme advanced by Dresch (1965), excess purchasing power would be eliminated through the tax system by diverting resources to investment rather than consumption goods. Under the plan, a program of forced savings through the issuance of investment certificates would be implemented. The investment certificates would be used to finance capital reconstruction. Another innovative proposal by Winter to provide incentives for savings is a deliberate policy of high interest rates.

The excess purchasing power problem could also be resolved through monetary reform. A number of authors have advocated a "blue money" policy in which a new scrip would be issued to replace the "greenback" at an exchange rate sufficient to eliminate excess liquidity in the economy. Other authors have discussed the need for backing the new currency with either gold or food supplies to ensure its functioning as a medium of exchange. Still other authors have speculated that multiple currencies will be required--at the state or federal reserve district level, for example--because there potentially could be a lack of confidence in a national currency.

With respect to postattack monetary policy, Winter argued that a deliberate policy of rapid inflation could restore solvency in the private sector. Rapidly increasing prices would tilt the debtor-creditor relationship in favor of the debtor and at least restore the paper solvency of the economy. Winter maintained that a policy of rapid inflation in concert with a private market system unencumbered by price controls would not lead to the abandonment of the established currency as a medium of exchange.

In a postattack economy, tax policy is also very important. Taxes can be used to redistribute wealth. A system of progressive income taxes, for example, can accomplish this purpose. The tax system can also be used to provide incentives or disincentives in various sectors of the economy. These incentives can be used to influence investment or production. The tax system can also be used to influence consumption. Excise taxes, for example, have been historically imposed to curtail consumption of various commodities. Taxes can also be used to influence the supply of inputs in production. In the postattack environment, the system of taxes will have an important impact on the amount and type of labor services offered to producers.

Authors discussing a postattack system of taxes have emphasized the need to use the tax system for directing resources into investment and away from consumer goods. Although a number of tax types have been suggested for consideration (a national sales tax, a value-added tax, progressive income taxes, estate taxes, capital gains taxes, taxes on

wealth), a comprehensive and consistent program of taxation has not been offered in the literature. One of the fundamental disagreements has been over the use of steeply progressive income taxes. It has been argued that progressive taxes are a valid means to redistribute wealth. On the other hand, some authors have argued that progressive taxes would stifle economic growth. To these authors, the redistribution of wealth should be handled outside of the tax system.

Not unrelated to the distribution of wealth issue, an approach to war damage compensation has received much attention in the literature. Critical considerations include questions of equity and efficiency. On the one hand, it has been argued that compensation for war damage may hamper economic efficiency, especially in the immediate postattack period. On the other hand, others have maintained that damage compensation is necessary to ensure the support of the population in the recovery effort. Because of this, the majority of authors have advocated some type of compensation program on both altruistic and pragmatic grounds, with the stipulation that it be implemented with the least disruption to the recovery effort.

Various types of compensation programs have been advanced in the literature. Hirshleifer (1954) outlined a war damage insurance program based on economic incentives that would induce the dispersion of assets and, hence, reduce economic vulnerability. A combination insurance-direct compensation program has also been advocated. Other authors have emphasized the need to develop a compensation policy in the preattack period because all other postattack planning--taxation policy, for example--hinges on the plan. The Federal Reserve Board's proposed Asset Validation Equalization Corporation (AVEC) has been given much attention. Under the AVEC proposal, government securities would be issued in compensation for destroyed assets to ensure at least the paper solvency of the economy. Other authors have emphasized the need for better preattack documentation of assets to ensure proper accounting in the postattack economy.

6.2. ECONOMIC ORGANIZATION AND STABILIZATION

Three of the most prominent themes in the literature on economic organization and stabilization have been (1) a critique of the federal government's presumed role in postattack economic recovery, (2) recommendations for that role, and (3) speculation on measures that the federal government can implement in the postattack economy to enhance recovery prospects. These issues will occupy the discussion in the remainder of this section.

Many of the contributors to the literature on postattack economic recovery have criticized the Federal government's plans for controlling economic activity in the event of attack. The object of much of the criticism has been the National Plan for Emergency Preparedness (hereafter the Plan)* which evolved out of the principles of economic control

*For a discussion of the evolution of the Plan, see Shaw Livermore (1968).

used in World War II. In part, the Plan allows the federal government to direct and control economic activity in an emergency period. In general, the primary criticism of the Plan is that it provides no specific details on what types of control devices are to be used, the responsibilities of government agencies in implementing it, and, perhaps most important, what forms of control will be established in the event that a significant portion of the national government does not survive an attack.

Winter (1968) questioned the ability of the federal government to implement the Plan. Winter made the distinction between

> . . . requirements for government action (under the Plan), as opposed to the capabilities . . . (Winter, 1968, p. 299).

Under the Plan, the federal government would require an extensive resource base to centrally administer the economy--resources that are, in Winter's view, not adequately ensured of survival after an attack.

Similarly, Sobin (1970) also criticized the Federal government's approach to management in the postattack economy. Among others, one of his primary concerns was the lack of planning to timely identify who should control private productive assets in the aftermath of attack. Based on his assessment of postattack problems, he concluded in part:

> It seems clear that there is a serious economic management problem. It is not possible now, and may never be possible, to provide an accurate estimate of the percentage by which less than perfect management degrades the potential performance of the economy after a nuclear attack. It is clear, however, that this percentage is significant under present plans and consideration should be given to ways that might reduce it. (Sobin, 1970, p. 12).

In evaluating prospects for recovery from nuclear attack, one of the recommendations of Greene, Stokley, and Christian (1979) was that research must be undertaken to develop a new plan to replace the current Plan, which they characterized as inadequate. Recognizing the large range of uncertainty surrounding attack levels and potential damage to the physical infrastructure, they advocated flexible strategies that would be contingent on various attack scenarios. In their view, a crucial part of the planning process should be a detailed definition of the functions of all levels of government in the postattack recovery process:

> The objective of this research would be to examine this controversy much more closely, looking at the tasks to be done, the powers and capabilities of the government, the data and analytical requirements, and so on. A general list of essential economic functions for government at all levels would be very useful, partly because it would help terminate what is believed to be a largely sterile debate over abstract economic ideology and concentrate effort instead on specific tasks. (Greene, Stokley, and Christian, 1979, p. 39).

Laurino and Dresch (1980) recommended that existing resource management plans should be modified. Moreover, because of the complex nature of the recovery management problem, the authors concluded:

> Even a cursory review of the current state of knowledge and emergency preparation is sufficient to convince one that the United States cannot currently implement the necessary policies or measures (for economic recovery). Nor are the current direction and scale of efforts likely to provide the capability for meeting those needs. (Laurino and Dresch, 1980, p. S-6).

General dissatisfaction with the Federal government's plans for managing the postattack economy has generated a substantial amount of debate in the literature over the past two to three decades on optimal postattack organizational arrangements of the economy. Recommendations for economic organization of the postattack economy have spanned the spectrum from at least temporary outright nationalization of all surviving resources to total reliance on a private, decentralized market mechanism. Winter (1966, 1968) has defined that spectrum and, for organizational purposes, has provided a convenient framework for discussion of the major issues.

To develop Winter's argument, he views the approach to economic organization and management in the postattack environment as a dichotomy between a highly centralized system and a highly decentralized system. Centralization and decentralization define the bounds on government involvement in postattack economic activity. Under a centralized system, the federal government would usurp the resource allocation decisions from the private sector, while those responsibilities would remain with the private sector under a decentralized system. However, in his view, the range of feasible alternatives for postattack economic management does not span the continuum defined by the two extremes. Indeed, the two extremes define the only feasible choices from which to choose. Winter wrote:

> . . . the range of possible forms of economic organization during the reorganization period is much more clearly dichotomized between relatively centralized systems depending on compulsion and relatively decentralized systems depending on private incentives than is normally the case. (Winter, 1966, p. 425).

Under this dichotomy, the choice of a decentralized system would limit the federal government's role in postattack recovery to economic institution-building.

Winter further argued that, because of management resource limitations, the two approaches are not complements to one another:

> Thus, the program of direct controls is an expensive and low priority adjunct of a program of institutional recovery, while the program of institutional recovery is an expensive, inessential and perhaps counterproductive adjunct of a program of

detailed planning and direct controls. A choice is called for. (Winter, 1968, p. 307).

Under the centralized option, Winter argued that the most efficient approach would be to nationalize all resources other than personal belongings ("disaster socialism"). The rationale for this argument is that nationalization would ameliorate many of the problems associated with controlling the postattack economy. Nationalization would eliminate many of the important economic institutional problems that are likely to be encountered in the postattack economy. Nationalization and total direct government control would preclude the need to re-create a price system, a medium of exchange, property rights, a banking system, and the like because all economic activity would proceed on the basis of government fiat. Resources would be allocated by a central authority that presumably has knowledge of surviving assets--both physical and human--and the regional dispersion of those assets.

However, under centralization of economic activity, the government would be required to direct economic activity at the finest level of detail. In Winter's view, the major problem with this approach is that an "enormous central bureaucracy" would be required to implement the program--a bureaucracy that could be assured of survival in the postattack environment only with preattack preparation expenditures of enormous levels.

While recognizing that the second alternative--a decentralized system with private incentives--would also require extensive preattack and postattack preparations, Winter advocated implementation of this alternative because

> . . . it would be much easier to assure the survival of the capabilities for accomplishing these tasks, essentially because no single administrative unit needs to be charged with elaborate responsibilities . . . not by comparison with the alternate scheme. (Winter, 1966, p. 427).

Winter's advocacy of limited federal participation in economic recovery is, therefore, based on a pragmatic argument. Given both the historically low levels of preattack budgetary outlays for establishing, maintaining, and protecting the economic control apparatus and the importance of time in promoting recovery ("The course of postattack economic events is likely to be determined . . . from three to nine months after the attack"), Winter argued that the most reasonable choice for the Federal government would be to concentrate its postattack efforts on reviving the institutional infrastructure that will afford the private sector the ability to function. Aspects of this institutional revival include the dissemination of information to guide expectations; the reestablishment of the legal, political, and monetary systems; and the restoration of basic regulatory functions, held by government in peacetime. In Winter's view, any attempt by the Federal government to participate directly in the allocation of resources in postattack economic recovery, without elaborate preattack preparations, would be counterproductive.

A number of other contributors to the literature on postattack economic recovery, writing both prior and subsequent to Winter, have provided arguments consistent with Winter's contention. That is, the optimal approach to postattack economic organization should not include nationalization of private resources but should rely on a decentralized system of resource allocation, supplemented by government involvement in economic institution-building. The authors include the participants in Panel D of the Project Harbor Workshop [National Academy of Sciences (1963)]*, Brown and Kahn (1964), Quester (1979), and Greene, Stokley, and Christian (1979). Their arguments will be discussed in turn.

The participants in the Project Harbor Workshop argued that nationalizing economic resources would be ill-advised as an approach to managing the postattack economy. After delineating the features of different approaches to managing the economy (private ownership with stabilization, nationalization of key sectors of the economy, "disaster socialism"), the authors concluded that the most extreme form of government intervention in the postattack economy must be eliminated from consideration:

> Historical experience, the ideological bases of American society, plus the likely disproportionate damage to the governmental mechanisms of authority, all combine to indicate the undesirability of generalized disaster socialism as the dominant postattack economic form. (National Academy of Sciences, 1963, p. 45).

Brown and Kahn (1964) questioned a centralized program of wage, price, and rent freezes, consumer goods rationing, and direct industrial allocation schemes in a postattack economy. Although they maintained that the four arguments used to justify centralized control in prior wars have merit--equity, inflation control, market breakdowns, and control effectiveness--they argued that the circumstances in a postattack world would be drastically different. In their view, one of the most important differences between a postattack economy and the economies of prior wars is that the prior ones had a specific "cut-off point" for the elimination of controls. Since there is no firm cut-off point in postattack recovery, the authors argued that

> The danger of firmly entrenching central planning as the predominant mode of economics in the United States would thus be greatly enhanced. (Brown and Kahn, 1964, Volume Two, p. 6-31).

Besides the danger of controls becoming entrenched in the American economy, the authors argued in a manner not dissimilar from Winter that a centralized system of controls would be impossible to administer because of the complexity of the economic problems confronting the central

---

*Winter was a participant in that workshop. Other participants were Jack Hirshleifer (Chairman), Lloyd Eno, Robert McGinnis, and Oscar Morgenstern.

administration. The authors argued that the challenge confronting preattack planning for postattack economic recovery is a formidable one:

> The problem of postattack recuperation should be seen as one of designing programs to avoid the effects of economic controls found critical during the survival stage. Unfortunately, the great efforts spent in devising schemes for the perpetuation of these controls may, on balance, hinder rather than help the recuperation. (Brown and Kahn, 1964, Volume Two, p. 6-32).

Quester (1979) provided options that should be considered for accelerating postattack recovery. The premise underlying the recommendations is that the major problem for postattack recovery is that the United States may not realize its full potential for recovery because of failures in postattack management. Moreover, recognizing that the required financial support for adequate peactime planning is not likely to be forthcoming, he argued that

> . . . the best hope for improvement is to look for marginal adjustments in our continually evolving peacetime management systems, adjustments which might contribute substantially to postattack recovery at little peacetime cost. (Quester, 1979, p. vii).

Quester was a strong advocate of private enterprise in the recovery effort. His basic position was that the best strategy for promoting economic recovery is the restoration of free market conditions. The approach used in his discussion of postattack options was defining the institutional environment in which business firms function. Given this economic setting, he maintained that the major role of the Federal government should be to plan for the reinstitution of that environment. Only in this way, Quester argued, can recovery be promoted.

Besides the inherent efficiency of a free-market economy, Quester maintained--like Winter--that, because of the destruction of Federal management resources and the need for surviving resources to devote efforts to more immediate problems, extensive government intervention in the postattack economy will not be feasible. The role of the federal government

> . . .should be more selective and less comprehensive, more tailored for specific opportunities than an attempt to replace the entire market process with some sort of 'war socialism' or 'disaster socialism' command economy. (Quester, 1979, p. 58).

Greene, Stokley, and Christian (1979) summarized the state of knowledge on prospects for recovery from nuclear attack. They identified six obstacles to recovery and proceeded to assess research on each of the obstacles, both by reviewing published research and holding discussions with acknowledged experts in the respective fields. One of the six obstacles identified in the study was economic breakdown. With respect to the management of economic resources, they argued that those responsible for postattack economic planning should seriously consider

the substantial problems with central economic control and, therefore, should rely to the largest degree possible on the decentralized market economy.

To a large extent, Greene, Stokley, and Christian agreed with Winter's arguments. Recognizing that the capabilities of the Federal government would be limited in the immediate postattack period, they argued that

> . . . there is serious doubt about the usefulness of nationwide production plans developed by the federal government, or how they could be implemented in the early phases of the recovery effort. (Greene, Stokley, and Christian, 1979, p. 39).

Other authors have called for more direct participation by the federal government in postattack economic activity. Hirshleifer (1965) speculated that, at least in some areas of the postattack economy, the government will be engaged in some form of direct control. Brown and Yokelson (1980) discussed the merits of some form of nationalization in various phases of the recovery effort. Dresch (1964, 1965) and Laurino and Dresch (1980) called for extensive government participation in the postattack economy, short of total nationalization of resources.

Hirshleifer (1965) speculated that the federal government will control a number of vital resources in the postattack environment (information being one of the most important) and, therefore, presumed that

> . . . there will be a national government engaged in some kind of overall regulation of the economic system . . . (Hirshleifer, 1965, p. 15)

in specific regions of the country that have suffered extreme losses. The degree of control will depend to a large extent on the phase of recovery and level of damage in a particular area. Therefore, some form of disaster socialism--direction of all economic activity by fiat--may be unavoidable in the initial period after the attack (the population maintenance phase of recovery). However, he did not advocate nationalization as the solution to economic resource management problems:

> . . . quasi-military rule will prove to be unavoidable for the damaged areas in the emergency phase, to be gradually relaxed as physical hazards abate. In the undamaged areas, and in private productive activity in general, new forms of government intervention will be found necessary. (Hirshleifer, 1965, p. 19).

Brown and Yokelson (1980) considered policies that could be important in facilitating economic recovery in the context of both their feasibility of enactment and the amount of research undertaken on their effectiveness. They considered 25 topics relating to both mobilization during an international crisis and reorganization after a nuclear attack.

With respect to the management of resources, Brown and Yokelson suggested a policy of at least temporary nationalization to manage resources during a period of international crisis. They based their argument on several presumed features of the economy during the crisis period. Included among these features were the private incentive to hoard important stocks of critical materials, the inefficiency of various control mechanisms (rationing and allocation schemes, for example), problems with large profit and losses in the private sector, and the potential ability to use nationalized resources as support for a currency.

Under this policy option, management of the nationalized economy would have dual centralized/decentralized features. The management system would be characterized by Federal control--providing guidelines and goals--and local control of existing assets, with the existing private-sector management structure acting as agents of the Federal government. The key feature of the proposal is decentralized management. Brown and Yokelson concluded:

> . . . our present belief is that during a nuclear crisis, nationalization without provision for decentralized management would probably constitute a serious mistake. (Brown and Yokelson, 1980, p. 23).

Brown and Yokelson's proposal for nationalizing resources encompasses the crisis period and would not necessarily continue over the entire recovery period. They argued that the relationships established between the Federal government and "paragovernment" managers in the crisis period could possibly serve as the basis for economic management during the early reorganization period before reversion to a private system of ownership:

> . . .if nationalization were reasonably effective preattack, it could be extended into the postattack reorganization period to help form an operating basis for an effective surviving government before being dismantled in favor of private ownership. (Brown and Yokelson, 1980, p. 34).

Dresch (1964, 1965) proposed a system of national scheduling and selective economic intervention to control and manage the postattack economy. Four circumstances in the postattack world dictate abandonment of a purely free-market solution to postattack economic problems: (1) drastic shifts in demand from traditional consumption sectors to defense and survival goods; (2) disproportionate damage; (3) disruption of market and distribution arrangements; and (4) the need for very rapid adjustment to the three changes. While Dresch argued that the restoration of a free market is important,

> The restoration of a system of markets and prices must be paramount among recovery goals, not merely to preserve familiar institutions, but to restore the most effective mechanism ever developed for expressing value preferences (Dresch, 1965, p. 2),

he maintained that, because of the aforementioned characteristics of the postattack economy, a free market pricing mechanism must be supplemented with a series of controls in the immediate postattack period:

> . . . the condition of the market and pricing system will greatly affect the efficacy of various types of control; and indeed the major purpose of some controls will be to facilitate, supplement, or substitute for the normal operation of the competitive market. Postattack recovery will require integrated development of pricing policy and other specific controls in a package of mutually consistent components. (Dresch, 1965, p. 5).

Dresch dismissed centralized control as "hopelessly unwieldy", but argued that strong, central policy guidance is a necessity in the early postattack economy.

In a later report by Dresch in collaboration with Laurino [Laurino and Dresch (1980)], the same emphasis on government intervention was reiterated. With respect to government involvement in industrial recovery, they observed:

> Following a heavy attack on industry, the Federal Government may have to 'manage' the economy much sooner than is currently believed possible. At the very least, the Federal Government must be able to marage the production and consumption of essential products early in the postattack period. (Laurino and Dresch, 1980, p. S-6).

Furthermore,

- Some of the countermeasures that are part of industrial strategies would require government control and acquisition of private property on a scale not heretofore envisioned. Considerable government efforts would be required during the planning and implementation phases to assure that the process is as equitable as possible and that the long term consequences to recovery are acceptable. (Laurino and Dresch, 1980, p. S-8).

In summary, the general theme permeating the literature on economic organization and stabilization in the aftermath of nuclear attack has been the importance of relying on the private market mechanism for allocating resources. Indeed, authors who have speculated that nationalization of economic resources may be required in some localities or over some time period--Hirshleifer (1965) and Brown and Yokelson (1980), for example--have acknowledged the need to return to the price system as rapidly as possible. However, most of the contributors to the literature have also acknowledged the need for different levels of government to take an active participation--to varying degrees--in managing the economic system. Although the role of the government in economic management is interpreted somewhat differently from author to author, a general theme is that a system of wage, price, rationing, and allocation controls that have been used during prior wars are not necessarily appropriate in a postattack environment.

For example, the participants in Panel D of the Project Harbor Workshop on issues related to the social and economic aspects of a postattack recovery program [National Academy of Sciences (1963)] felt that the economic stabilization approaches used in World War II have had undue influence on the Federal government's planning for recovery from nuclear attack. They argued that the relevant historical analogue is not the economy of the United States but the reconstruction of the economies of Germany and Japan in the aftermath of World War II. Among other factors, the authors cited a lack of economic managerial skills as a reason for not imposing World War II-type control measures on a postattack economy:

> . . . the skills required for government control of economic functions, such as how to ration, when to grant a price increase, whether to force an enterprise to close down, or alternatively to continue unprofitable operations, are not acquired in peacetime in our predominantly private-enterprise economy. (National Academy of Sciences, 1963, p. 44).

Writing a decade and a half after the Panel D Workshop, Greene, Stokley, and Christian (1979) also argued against using control mechanisms of the type used during World War II. After discussing the features of control mechanisms used in World War II, the authors concluded:

> Conditions would be quite different following a nuclear war...The problems of the government would be much different than they were in the early 1940's and 1950's when it was a matter of setting goals and waiting for industry to file (Controlled Materials Plan) requests. Unfortunately, much of the thinking about resource allocation is based on our successful World War II experience. Standby plans and orders to reinstate the system are in the emergency books waiting for proclamation by the President. (Greene, Stokley, and Christian, 1979, p. 42).

Given the inapplicability of World War II-type controls and the limited capability of the federal government in the postattack environment, the critical question to Greene, Stokley, and Christian was how economic resources should be allocated. Calling that problem

> . . . a matter of grave concern which has so far received little attention (Greene, Stokley, and Christian, 1979, p. 42),

the authors called for a research program to develop effective control mechanisms.

Given the general disillusionment with the types of controls used in World War II, several contributors to the literature have advocated other conventional and somewhat unconventional approaces to government participation in the postattack economic recovery effort. These authors include the participants in Panel D of the Project Harbor Workshop [National Academy of Sciences (1963)], Winter in Appendix J of the documentation of that workshop, Sobin (1970), Hirshleifer (1965), Quester (1979), Brown and Yokelson (1980), Dresch (1964, 1965, 1968a, 1968b),

and Dresch and Ellis (1966, 1968). An overview of their proposals will occupy the discussion in the remainder of this section.

In general, the participants in Panel D of the Project Harbor Workshop [National Academy of Sciences (1963)] recommended a private enterprise economy augmented by select government intervention. For heavily damaged areas, they argued for centralized organization and control in the immediate emergency phase of recovery. The justification for this type of intervention is to alleviate physical--not economic--problems such as mass feeding, evacuation, and decontamination through a paramilitary form of control. For undamaged areas--and after the problems in damaged areas have been resolved--centralized control of economic resources could not, in the authors' view, be justified. Indeed, the participants argued that any attempt to centrally control the economy would be misguided:

> We regard this approach as seriously mistaken. The detailed relevant information distributed among all economic agents can never be perfectly funneled into the center; also, even a perfect centralized plan could not be executed by scheduling humans to perform tasks like machines--the problem of providing incentives would still have to be faced. (National Academy of Sciences, 1963, p. 46).

The authors argued for a privately owned and managed economy augmented by a set of limited controls imposed by the Federal government. Included among these controls would be restrictions on purchasing power in place of more traditional types of controls used in World War II (material allocations, wage and price freezes, and consumer rationing). Also, the authors argued for a large government role in key industries--interregional communication and transportation, as examples.

With respect to recovery, the authors conceded that, besides all of the uncertainties associated with nuclear attack (targeting and a protracted conflict, for example), economics and the other social sciences do not lend themselves well to exact answers. Therefore, they proposed a set of programs that are flexible enough to accommodate a wide array of conceivable postattack situations:

> There is urgent need for research into the functioning of social and economic systems under severe stress, with special attention to the problem of social control with damaged administrative mechanisms. (National Academy of Sciences, 1963, p. 46).

In an appendix to the Project Harbor study, Winter [National Academy of Sciences (1963), Appendix J] proposed some unconventional approaches to economic control under the assumption that a lack of sufficient managerial resources in the Federal government will limit its involvement to implementing select, strategic controls essential for national recovery. Winter's primary concern was developing realistic price signals for postattack resource allocation. The problem is especially important in a postattack economy because relative prices that existed immediately preceding an attack will not be realistic after

large-scale and disproportionate destruction of economic resources. Winter discussed three possible solutions to the problem: (1) establishment of futures markets; (2) government-determined advisory prices; and (3) selective price guarantees.

Winter's proposed system of futures markets would, at a minimum, encompass commodities which are essential for survival. The rationale for the system of futures markets is that a relatively uncontrolled free market economy in the aftermath of a nuclear attack--the assumption on which Winter bases his proposals--does not have a built-in mechanism for intertemporal and intercommodity resource tradeoffs that would ensure investment in the highest priority sectors. Futures prices would provide signals for the current period allocation of resources to their most urgent and productive uses.

In the absence of futures markets, Winter argued that the Federal government should somehow assure that proper price signals are guiding investment. One approach would be for the government to establish unenforced control prices or "advisory prices." The prices would be based on an assessment of damage to productive resources and would have the advantage of at least placing a relative value on the stock of critical inventories. Here again, the purpose of providing price information would be to ensure that investment decisions are guided by an estimate of realistic relative prices.

Another possible approach for ensuring investment in critical industries in the absence of a functioning price system would be for the government to guarantee the price of crucial commodities. This would alleviate the problem of making investment decisions based on uncertainty of future prices.

Besides suggestions for developing realistic price signals to guide the allocation of resources, Winter argued that the Federal government should actively participate in at least three other areas of the postattack economy. First, Winter argued that supporting industries--transportation, electric power, communications, water and sewerage systems--are logical candidates for government intervention. Among the reasons advanced for control of these industries, Winter argued that they are important for the effective operation of other industries and their large capital requirements with relatively long construction lead times could pose problems in reconstruction.

Second, Winter drew an analogy between a postattack economy and the problems confronting developing economies in their attempt to divert resources from current consumption to investment at a period of time when consumption is at a very low level. One of the possible solutions to guiding the economy away from current consumption is a deliberate policy of high interest rates. Although Winter acknowledged the inevitability of high interest rates in a postattack economy because of the normal interaction of market forces, he argued that the level of interest rates will have little effect on investment decisions for securities that were in existence prior to an attack. Therefore, he proposed the creation of new types of securities to attract investment. An example is a low-denomination, short-maturity, negotiable "purchasing power bond."

Third, Winter addressed the problem of equity versus efficiency in the distribution of essential survivor commodities. Inequitable distribution could lead to social discord that would hamper recovery activities. On the other hand, misguided attempts at equitable distribution of essential commodities would be an impediment to production. As an example of the latter, Winter argued that price controls on essential commodities could establish prices at a level that would dampen incentives to produce these goods. In this circumstance, a more efficient solution may be to issue ration stamps so as not to hamper production of essential commodities.

In a critical assessment of the Federal government's plans to control the postattack economy, Sobin (1970) was concerned with the government both usurping the power of the private sector to allocate resources and allowing the private sector to function unrestrained. On the one hand, resource allocation decisions made by government agencies are inherently inefficient and any attempt to improve the control mechanism would be fruitless. On the other hand, reliance on the market mechanism would not be an attractive alternative either because Sobin envisioned problems with the length of time that it would take relative prices to provide the proper signals in a market economy:

> Conceivably, there could be a period of wild price fluctuation with potential producers unable to predict with any confidence what the prices will be at the time their production plans mature. During such a period, there could easily be surplus production of some items and insufficient production of some other items for which there is plenty of capacity. Such miscalculations occur to a significant extent even under the relatively stable conditions of peacetime; they would be much more serious and widespread immediately after a heavy nuclear attack. (Sobin, 1970, p. 12).

Unfortunately, Sobin did not prescribe specific solutions to the economic management problems that he foresaw in the postattack economy.

As discussed above, Hirshleifer (1965) argued that nationalization of resources may be unavoidable in severely damaged areas at least through the population maintenance phase of postattack recovery. However, for the longer term reorganization and recuperation phases, he argued that extensive economic control by the Federal government would not enhance recovery prospects. After reviewing the use of World War II-type controls in Germany and Japan, Hirshleifer concluded:

> It seems evident, retrospectively, that much wiser policy would have dictated control of inflation by limiting the emission of purchasing power, without attempt to freeze prices and economic relationships at unrealistic levels. Indeed, the real beginning of postwar recovery of each of these countries was associated with just such a shift of policy. (Hirshleifer, 1965, p. 18).

Hirshleifer's recommendation for recovery from the large-scale destruction of physical and social relationships was focused on attainment of one goal:

> The object here will be to find a way, despite unavoidable inequities, to liberate private productive energies from the dead weight of past claims and contractual arrangements. (Hirshleifer, 1965, p. 19).

To accomplish this, Hirshleifer cautioned that government intervention beyond what was used in World War II will be required. The new forms of intervention that Hirshleifer discussed were (a) the guarantee of private transactions with financial institutions; (b) emergency credit; (c) moratoria on various types of property income and (d) currency reform. The recommendations all fall short of total government control of economic activity and are oriented to reinstitution of the institutional infrastructure.

Quester (1979) argued that advance planning by the Federal government should be concentrated in four areas that will facilitate recreation of the proper institutional infrastructure for the operation of a private enterprise economy: (1) the communication system must be restored as rapidly as possible; (2) alternative banking arrangements must be instituted; (3) a monetary system must be established; and (4) commodities and securities markets must be restored as quickly as possible.

With respect to the government's role in the recovery effort, Quester emphasized that it should be restricted to areas in which there is a severe misallocation of surviving resources and lack of government intervention and coordination would lead to precipitous price increases. In part, he concluded:

> The optimal solution for the government, even when considerations of justice and of need are taken into account, may thus sometimes be to let prices find their own level in the general reconciliation of supply and demand, while trying to make sure that supply is adequate for most sectors and trying to secure control and ownership of some important commodities as part of establishing a 'currency' of sorts, to maintain its overall authority. (Quester, 1979, p. 57).

As discussed above, Brown and Yokelson (1980) argued that a possible solution to the postattack recovery problem would be to nationalize private resources during a period of international tension and possibly to extend that type of control into the recovery period. However, in the event that nationalization is not relied on to solve the economic management problem, the authors maintained that wage, price, and rent freezes that were used in other wars would not necessarily be appropriate in the aftermath of nuclear war. The Federal government should not implement stabilization policies because, among other reasons, they would not have time to be effective in the immediate aftermath of an attack. They concluded that an appropriate policy is one which recognizes that stabilization measures should be developed spontaneously at the local level:

> . . . one suggestion that appears to be worthy of consideration would be for the federal government to avoid trying to set postattack prices, wages, rents, or other methods for settlement of debts, contracts, etc. To a large extent, effective postattack procedures might best be improvised--probably first at local levels. However, if the federal policy is to be effective and acceptable, postattack, it would need to provide some guidelines which indicate the eventual amount of support that the national government itself would offer. (Brown and Yokelson, 1980, p. 40).

Dresch and Ellis (1966) developed a qualitative model of U.S. society to identify institutional problems that could arise in the aftermath of a nuc..ar attack. In contrast to previous system studies, the emphasis of their analysis was not only on the physical infrastructure of the economy, but also on the institutional infrastructure--both economic and sociopolitical institutions. They characterized U.S. society as a large system, composed of three broad, interacting subsystems: an economic system, a political system, and a sociocultural system. They further disaggregated these three subsystems into 23 institutions that comprise the institutional infrastructure of the United States. Using this systems analysis approach, the authors identified both inputs and outputs to the interacting subsystems to isolate the indirect effects of a hypothesized nuclear attack on society. Unfortunately, as the authors acknowledged, the results were speculative because of the nonrigorous characterization of the interacting subsystems.* That is, insufficient knowledge of the precise quantitative relationships between various facets of the subsystems proved prohibitive in deriving specific conclusions. However, the authors concluded that damage to the institutional infrastructure may be more of a problem in the postattack environment than destruction or impairment of physical resources.

In a subsequent study, Dresch and Ellis (1968) focused their attention on the consequences of the impairment of six institutions in the postattack economy--four economic institutions (solvency, money and credit, business management, and normal business channels) and two political ones (legislative imbalances and election machinery). These six institutional aspects were selected for detailed analysis because of their importance in postattack recovery and the fact that they are more amenable to detailed research.

Based on their analysis, Dresch and Ellis concluded that postattack management of economic resources is the singlemost important factor in economic recovery:

---

*In two subsequent reports, Dresch (1969a, 1969b) developed a prototype or pilot quantitative representation of the economic subsystem. Although the model could be used to simulate varied aspects of postattack recovery, the focus in the two reports was on fiscal problems. Concisely, the model was a nine-sector input-output representation of the economy that characterized production relationships using a Cobb-Douglas production function and explicitly modeled final demand on the basis of variables theorized to influence sectoral demand.

> The principal threat to national viability even under the most adverse circumstances appears to be the possibility of mismanagement of early rehabilitation and recovery efforts. (Dresch and Ellis, 1968, p.4)

However, the authors argued that it is difficult to develop a management plan for postattack recovery because of the uncertainty of conditions in the postattack environment. Therefore, they called for a flexible plan for economic recovery with implementation details determined in the postattack period.

One of the organizational problems that they addressed was relationships among the various levels of government. For economic matters, they evaluated the role of government in a free market economy. Recognizing that controls can have a "disturbing influence on the economy," they nevertheless concluded that the nature of the problems confronting economic management necessitates controls never before experienced in U.S. history:

> These and other rigidities or anomalies would force a vast increase in the involvement of government in economic matters. Moreover, the relationships among federal, state, and local governments would be very different from their normal character. Business would be heavily affected by government regulation in unprecedented ways; this regulation would come from all levels of governmental authority. (Dresch and Ellis, 1968, pp. 43-44).

Dresch (1968a) reiterated the necessity of direct government involvement in the economic recovery effort. Although he recognized that the severity of the economic recovery problem would vary with the level of attack, he argued that economic problems would be pervasive in any type of attack. One of the underlying problems would be a sudden shift in demand across the economy which would blur cost relationships and, therefore, would pose problems for the private sector in choosing among alternative business strategies. These circumstances would lead the Federal government to intervene in the economy (price freezes, rationing, emergency allocations) which, in turn, would increase uncertainty in the postattack economy.

In this setting, because of the detailed, localized nature of the economic problems that the country would confront, Dresch concluded that all levels of government must necessarily be involved in the recovery process:

> A federal echelon is essential to preserve national interests, a local echelon is essential for practical management decisions, and a state echelon is essential for political reasons. (Dresch, 1968, p. 370).

Moreover, repeating the theme of his earlier work that rigid organizational planning for postattack recovery is not desirable in the preattack period, he further concluded that more research is required on the postattack manangement problem:

> Present insights into probable postattack conditions must be sharpened considerably before organizational and informational requirements can be determined adequately, and this is a legitimate concern of postattack research in the preattack period. (Dresch, 1968, p. 371).

In an earlier two-part study, Dresch (1964, 1965) discussed both the features of a national production scheduling system and select government intervention in the economy in the postattack period. In Dresch's view, management of the economy should be based on integrating federal and local responsibilities. Economic decisionmaking would reside at the local plant level. The production decisions would be consistent with national planning developed by a proposed Recovery Production Agency (RPA).* One of the characteristics of this management scheme would be a national information system--a master scheduling system--in which the primary purpose would be to report information on productive capacity and material flows. In Dresch's view, the system should be composed of two levels of scheduling--a Federal level central scheduling agency (CSA) and 509 disaggregated state economic areas (SEAs). The CSA would be responsible for preparing master production schedules and for coordinating those plans with the various SEAs. The latter would presumably have direct access to information on industrial activity in their respective regions. The CSA would report to the RPA.

Dresch envisioned that the interactions of the SEAs, CSA, and RPA in terms of providing master schedules for production levels in the economy would determine the overall goals of the economic system. However, he argued that other types of intervention would necessarily be required:

> . . . the imperfections in the market mechanism and in the scheduling system would require supplementary controls of far more detailed character than ever attempted before in the U.S. economy. (Dresch, 1965, p. 2).

Besides rationing and price controls, Dresch argued for government intervention to ameliorate problems in other areas of the postattack environment. Included among these areas were transportation and communications systems; use of labor; aid to heavily damaged regions and industries; housing-related aid; reconstruction of some industrial facilities; the reorganization of distribution; and establishment of the financial basis of the economy.

With respect to rationing and price controls, Dresch argued that they are inevitable in general and inescapable for certain essential

---

*Dresch does not argue that the RPA should be a separate and distinct institution from the federal agency responsible for emergency preparedness (at the time of writing, the Office of Emergency Preparedness). Rather, his point is that an institution empowered to direct the overall performance of the economy must be established--the OEP with additional responsibilities, for example.

commodities. However, Dresch cautioned against their use in a manner inconsistent with other types of controls:

> The need is thus for integrated development and implementation of the whole system of controls to avoid conflicts and incompatibilities not desired for checks or balances. (Dresch, 1965, p. 32).

Dresch argued that price controls and an associated rationing scheme should not be used to control inflation but should be used for goods that must necessarily be distributed equitably over the surviving population (survival goods) and for goods that are limited in supply because of production limitations imposed by the RPA. Dresch's resolution of the inflation problem involves limitations on consumer spending--a system of forced savings, for example. The conduit through which forced savings would be implemented is the tax system. Under this scheme, besides the normal withholding of income for general tax purposes, an additional amount would be withheld for recovery investment. Investment certificates would be issued that could be converted into government bonds, corporate securities, or used as direct investment in capacity expansion allowed by RPA. Since the system of controls would be a temporary phenomenon, the withholding for investment certificates would be gradually phased out as the need for investment funds became less of a problem.

In a later work, Dresch (1968b) outlined the features of an information system that would be required to cope with the institutional problems that were identified in his earlier work. For information flows in recovery management, Dresch amended his master scheduling approach for directing production in the postattack period. Under the master scheduling approach, the central authority would have a large responsibility in directing postattack recovery. In Dresch's revised proposal, he argued that the first two months of the postattack period are critical for decisionmaking and the time frame is too short for effective central intervention in local productive activity. Therefore, he argued that free markets at the local level should be relied on to guide productive activity. In this scheme, the role of the Federal government would be to control critical materials and major investment decisions.

Other authors have outlined features of management information systems for enhancing recovery prospects in the postattack period. Massell and Winter (1961), for example, delineated the design of a postattack damage assessment system. The scope of the information system was limited to two types of activities: (1) attack surveillance and (2) resource evaluation. In Massell and Winter's view, a damage assessment system must be able to survive an attack and be integrated into the postattack decisionmaking process. With respect to the latter characteristic, the authors identified three classes of decisions: strategy, immediate survival activities, and economic organization.

For the latter type of decision, the authors provided a caveat. Here, they made a distinction between a highly centralized and decen-

tralized economic management system and concomitant information requirements:

> Thus the requirements for an information system which will provide guidance for detailed control of the economy are much more demanding than those for a system which simply provides a general orientation. Unless considerable attention is given ahead of time as to how the information system is to relate to the decision makers and to the available techniques for controlling the economy, its usefulness in the reorganization period may be very limited. (Massell and Winter, 1961, p. 49).

Black and Van Horn (1970) devised a program to estimate local productive capacity following a nuclear attack. Local efforts at estimating postattack capacity would be organized within a broader national context to determine national productive capacity. The procedures developed by Black and Van Horn included three surveys which would serve as the basis of the assessment. The first, termed the Orientation Survey, was proposed as a quick on-site assessment of capacity following an attack and estimates of capacity that would be available after repair. The Planning Survey, tentatively scheduled to be completed within a few weeks after the attack, would provide a more detailed estimate of productive capacity under various repair scenarios. A Detailed Survey would provide engineering specifications of the effort required to restore a damaged facility.

6.3. THE MONETARY SYSTEM

The two most prominent themes in the literature on the postattack monetary system are the advantages of issuing a new currency to replace the prevailing currency in the immediate postattack period--the so-called "blue money" proposal--and the potential importance of backing a new currency with an essential commodity--food reserves or gold, for example--to ensure its effectiveness as a medium of exchange. Another theme in the literature is that the Federal government may have to plan for the use of multiple currencies in the immediate postattack period. Additionally, Winter (1966) outlined an unconventional policy of rapid inflation to resolve some of the financial problems in the postattack economy.

Proponents of a "blue money" approach were the participants in Panel D of the Project Harbor Workshop [National Academy of Sciences (1963)] and Brown and Yokelson (1980). Brown (1970), Quester (1979), and Greene, Stokley, and Christian (1979) advocated backing the currency with a valuable commodity.

The participants in Panel D of the Project Harbor study viewed the "blue money" proposal as one way of solving the postattack purchasing power problem. The blue money would be part of a currency reform to eliminate excess liquidity in the postattack period. "Greenbacks" would be exchanged for a new currency at an exchange rate sufficient to eliminate excess purchasing power in the economy.

Brown and Yokelson (1980) argued that the Federal government should stockpile a currency that can be used in the postattack economy. The currency would be differentiated from the current greenback. They gave two reasons for the preattack stockpiling. First, the use of greenbacks will, in all probability, lead to a rapid rise in the price level. Second, currency reform is a prerequisite for any type of economic organization based on market principles.

The authors advocated this approach because it is a relatively inexpensive preattack preparation that would save time in postattack economic management. The "blue money" would be printed preatttack and, in the postattack period, backed with surviving tangible assets. The currency would then be used to facilitate any transactions that the Federal government may want to undertake in the postattack reorganization. Examples of those activities include war damage compensation, Federal investment, and credit guarantees.

Depending on the nature of damage from an attack, Brown and Yokelson argued that another possible alternative would be to give currency stockpiling authority to individual states. The rationale is that confidence in the Federal government's currency may not be restored immediately after an attack.

In a 1970 study, Brown looked at problems that may arise if the Federal government did not survive in the postattack period and, alternatively, problems that may not be soluble even if it did survive. Under the latter circumstance, Brown emphasized the crucial role that money plays in a "loop of three elements" reorganization effort that includes (1) money, (2) Federal personnel, and (3) Federal authority. In part, he argued:

> The major problem (and solution) seems to revolve around sound money. If public confidence can be maintained in the dollar then the personnel can be kept (through preattack and postattack assurances) and the federal authority would be maintained by simple provisions of (the existing) continuity-of-government legislation. (Brown, 1970, p. 9).

Brown argued that plans must be established to maintain the money-personnel-authority loop if the Federal government is to be effective in postattack reorganization. A possible solution would be for the Federal government to purchase inventories of critical materials to redeem dollars for physical inventories. In this way, the dollar can serve as a medium of exchange.

Quester's (1979) major concern was that a sound preattack policy must be developed to avoid the inefficiencies of a barter economy:

> Anything that conversely looks and works like 'money' (pulled out of contingency vaults, having been prepared for just such a nuclear emergency), or a return to gold as the basic form of money, or a desolution into separate state or regional or Federal Reserve district currencies would be a much better solution than a reversion to barter. (Quester, 1979, p. 21).

In a barter economy, Quester argued, any number of very localized currencies could arise which could facilitate local transactions, but impede the efficiency of interlocal transactions. Likely currencies to arise at the local level include the issuance of currencies by individual banks or wealthy individuals who survived the attack.

Quester outlined a number of approaches that would increase confidence in a national currency. One approach would be a return to some type of gold standard. Under this scheme, the Federal government would announce a value for gold and actively engage in buying and selling it. The gold could be exchanged for existing Federal Reserve notes or, alternatively, for gold certificates printed preattack that could be exchanged for either Federal Reserve notes or gold. This approach would require that U.S. gold reserves be dispersed from one central location to ensure their survivability.

Another approach would be to back a currency with an important consumer good under a prespecified exchange rate. Examples of important consumer goods include gasoline and food. The two obvious requirements are that the Federal government must nationalize the commodity or commodities backing the currency and printed vouchers must exist, ready for distribution. Recognizing that there will be a geographically disproportionate destruction of resources, Quester did not eliminate the possibility that multiple currencies may have to be adopted.

Green, Stokley, and Christian (1979) called for research on money, credit, and banking in a postattack environment. They argued that the Federal government will be required to establish a monetary system to facilitate exchange and speculated that, at least in the early postattack period, the government should back the issuance of emergency scrip with supplies of survival necessities. Gold is a possibility to back money, but they maintained that the selection of this alternative may not be optimal because the supply of gold is limited and gold may not be amenable to rapid depreciation if that policy is pursued by the government.

Winter (1966) discussed the question of monetary reform in the context of property rights and solvency.* That is, the approach to postattack monetary policy is contingent on the ability of the Federal government to resolve issues associated with both ownership of private assets and disrupted financial relationships in the private sector, caused by the destruction of real property. Given that the government can at the very least assure the banking system's solvency, two issues are relevant: the government's policy with respect to inflation and currency reform.

*Winter assumed that preattack appropriations to ensure the survivability of management resources in the Federal government will not be forthcoming. He also assumed that insufficient managerial resources will limit the government's role to re-creation of the institutional infrastructure of the economy. For further background on this assumption, see the discussion in Section 6.2 on Economic Organization and Stabilization.

Winter argued that a "crude but probably quite effective means" to restore solvency in the private sector is a policy of rapid inflation. The basis for this argument is that, in a period of rapidly rising prices, the debtor-creditor relationship becomes increasingly favorable to the debtor. Thus, a policy of devaluing the purchasing power of the dollar would facilitate the ability of both firms and individuals to meet their financial obligations. In this way, economic agents would be freed from obligations incurred in the past that are unrelated to current economic conditions.

Winter dismissed two possible objections to a rapid inflation policy. First, on the question of the inequity caused by favoring debtors, Winter argued that

> . . . the haphazard patterns of destruction of wealth are already a cause of tremendous inequity, and the two sources of inequity may tend to cancel out--at least, they are not simply additive. (Winter, 1966, p. 430-431).

Second, Winter did not believe that the national currency will be abandoned under this policy. Alluding to Germany's experience following World War II, he argued that the barter economy that existed in Germany was not attributable to lack of confidence in the currency, but to the system of rationing and controls that was imposed fo wing the war.

Winter also argued that currency reform could play a significant role in an inflation policy. He maintained that if a currency reform were implemented in the immediate postattack period, it might be possible to avoid rationing consumer goods. This would be possible because the central authority would have direct control over the conditions under which currency exchange (old scrip for new scrip) would take place. Thus, the purchasing power of consumers could be controlled. On the other hand, if currency reform was implemented in a later period, a progressive system of conversion rates from old to new currency would ameliorate the inequities produced by the inflationary policy.

6.4. THE FISCAL SYSTEM

As with prior research on the monetary system, very little substantive research has been undertaken on a postattack fiscal system. The authors who have addressed issues associated with the fiscal system have generally emphasized the need for preattack tax planning. It has been argued that the tax system should the conduit for resolving the inequities of the postattack redistribution of wealth, for providing incentives, and for diverting current income to investment.

Winter (1966) cautioned against using the tax system in ways that could lead to inefficiencies in the recovery effort. He was especially concerned about using the income tax to redistribute wealth. The problem with pursuing this policy would be the simultaneous impact on incentives to work. He argued that a highly progressive income tax, for example, may increase the incentive to withdraw from productive employment, in favor of other activities that offer a greater opportunity for

tax evasion. His solution to this problem is basing the redistribution of wealth on assets that survive the attack, and not on income earned over a period of time.

Brown and Yokelson (1980) stressed the importance of taxation for both redistributing wealth and providing incentives for investment. With respect to the former, they argued that the use of taxation must necessarily be more stringent than ever encountered in U.S. history. They further argued that various types of taxes must be used. Included among them are proportional and regressive income taxes, estate taxes, capital gains taxes, and levies on the net worth of both business firms and individuals. However, they concluded that, because of the relative dearth of research undertaken in the area, they were not able to provide specific guidance on the type and degree of taxation:

> Studies to define the range of problems and offer recommendations for possible modes of action are needed at all government levels. These studies should include the possibilities that the government might tax windfall profits and impound scarce or critical commodities in order to effect an equitable distribution of resources. (Brown and Yokelson, 1980, p. 56).

For a tax policy to induce investment, they argued that the Federal government should play a large role in promoting investment. Here again, while they argued that the Federal government can "offer special tax inducements" for investment and can discourage the consumption of luxury goods which would attract resources to undesirable sectors, they did not offer a specific tax program.

Brown and Kahn (1964) argued that the demand for Federal government expenditures in the aftermath of a nuclear attack will be enormous. Besides a compensation program for war damage, the government necessarily must be involved in reconstructing buildings, roads, bridges, hospitals, educational institutions and the like. To generate revenues sufficient to make these expenditures, the government should consider a wide array of both nontax and tax revenue generating modes. For nontax devices, the authors proposed implementing a Federal escheat law, managing profitable enterprises, and selling property to which the government has title.

For traditional sources of revenue, the authors argued that discouraging consumption and encouraging investment are primary goals. The authors maintained, however, that there are problems with a system of progressive taxation. The system may stifle investment because of the "bunched income" phenomenon where investors do not initially realize substantial amounts of taxable income, but then make up for it in later years. The authors also pointed out that a system of progressive taxes are administratively unwieldy. The authors called for research on a number of other taxing alternatives. Included among these are a progressive consumption tax, a federal estate tax, a general sales tax, excise taxes, and tariffs.

Dresch and Ellis (1968), on the other hand, argued that progressive withholding taxes must necessarily be enacted in the postattack economy.

They argued that this tax type is necessary because of the potential disproportionate survival of unskilled as opposed to skilled and managerial workers. The progressive taxes would be a desirable alternative to wage controls because of the inefficiency of workers moving into higher skilled jobs.

Brown (1970) argued that, if some portion of the federal government survives an attack, the tax system should be used to induce desirable levels of investment and consumption. He maintained that special tax inducements should be enacted to stimulate investment and prohibitive taxes should be imposed to discourage consumption of luxury items. However, no specifics were offered.

In their proposal for a comprehensive research program to reevaluate postattack recovery planning and implementation, Laurino and Dresch (1980) foresaw significant problems with revenue generation at local levels because of the decline in property tax revenues and at the national level due to reductions in individual and corporate income taxes. They argued that rates in present tax laws should be revised in the postattack period or other tax measures such as a value added tax or national sales tax should be implemented.

6.5. DAMAGE COMPENSATION

The issue of damage compensation in the aftermath of both geographically localized disasters and relatively large-scale disasters has received much attention in the literature. For a large-scale disaster resulting from nuclear attack, two issues have dominated the literature. First, some form of war damage compensation will be mandatory, based on equity considerations. Second, a specific form of compensation must be developed that will not impede economic efficiency. The general theme permeating the literature on disasters resulting from natural phenomena is that a comprehensive system of disaster insurance is preferable over a system in which victims are compensated by ad hoc government expenditures. Individual contributions to the literature on damage compensation in the aftermath of these two types of disasters will be considered in turn.

Writing at the outset of the nuclear age, Hirshleifer (1954) advocated implementing a national war damage insurance program to compensate individuals for the loss of assets in the event of a large-scale disaster. The purpose of the national program is to let economic forces reduce vulnerability to attack. Insurance premiums based on risk of destruction in the event of nuclear attack would be the mechanism used to reduce vulnerability. That is, by providing differentials in insurance rates for individuals and corporations based on relative geographical vulnerability (for example, densely populated urban areas as opposed to relatively less concentrated rural areas), economic forces would tend to disperse the concentration of population and economic capacity over a period of time, resulting in a reduction in national vulnerability. Hirshleifer concluded:

> . . . from the economic point of view (defining the latter broadly to take into account questions of equity and administration), a plan for war damage insurance, with rate differentiation according to the best estimates available of the risks bearing upon the insured properties, offers a promising method for encouraging private expenditures having the effect of reducing the national vulnerability to bombing, while providing a procedure for compensation of individuals suffering damage due to enemy action. (Hirshleifer, 1954, p.26).

The implementation of Hirshleifer's insurance program necessarily involves participation by the Federal government in providing credit because of the magnitude of the potential losses. Hirshleifer did not rule out the participation of private companies to issue war damage insurance policies, but recognized the need for backing by the Federal government. While he did not present specifics on the structure of the premiums other than that rates should be differentiated on the basis of estimates of risk, he believed that the average rate should be set to ensure that revenues would cover expected losses, considering the probability of war. Compensation under the program would not be total. Hirshleifer argued that individual compensation should be based on relative destruction (or, conversely, survival) of assets caused by the attack.

Hirshleifer foresaw a number of problems associated with the insurance approach. Included among them are (1) insuring against the economic consequences of an attack (indirect loss of economic value or property) as opposed to tangible property; (2) implementing the plan on a voluntary or compulsory basis; and (3) problems with defaults or delays in providing compensation in the event of attack. However, in terms of private incentives to reduce vulnerability, Hirshleifer argued that an insurance program based on risk-differentiated premiums is more economically sound than other alternatives: no insurance with no compensation; no insurance with compensation; and insurance without differentiated rates based on risk.

In an earlier paper, Hirshleifer (1953) argued that, under assumed ideal conditions, the economic incentives afforded under a war damage insurance plan would lead to an optimal effect on national vulnerability in the sense that it would induce decreases in national vulnerability where the social gain exceeds the social cost. Hirshleifer wrote:

> What is more important is that such a schedule of differential rates will, through the price system, tend to encourage voluntary private actions in the direction of reducing vulnerability to bombing. For every possible step in this direction, an appropriately reduced insurance premium would (ideally) be offered. Clearly rational self-interest would lead to the adoption of all measures such that the private cost of change is less than the private gain in terms of reduced premiums. When these conditions apply, we may say that, at least as a first approximation, the social cost of change (diversion of resources) is less than the social cost (the risk of destruc-

> tion) of maintaining the status quo. (Hirshleifer, 1953, p. 6).

Brown and Kahn (1964) argued that an optimal war damage compensation program would include both an insurance system and a direct compensation plan. An insurance program, in their view, has compliance problems. If the system is compulsory, it does not act as an insurance scheme but merely serves as a tax, with a promise-to-pay from the government in the event of damage resulting from nuclear war. On the other hand, if it is voluntary, there may not be sufficient incentive to join the program, thus defeating its purpose. And, there will not be sufficient reserves to compensate for war losses.

Brown and Kahn highlighted some of the more important features of a damage compensation plan. Like many other authors, they argued, on efficiency grounds, that a war damage compensation program may impede economic recovery. On an equity basis, however, they argued that some type of compensation program must be implemented to ensure that the surviving population will support the government.

Given the need for a compensation program, the authors raised a number of questions with respect to implementing the program. First, property coverage would be a problem. If the only property covered under the program were commercial and industrial assets, the administrative burden would be easier. However, if the overall goal of the compensation program is equitable distribution of losses, no case can be made for excluding private consumer goods and luxury items. Indeed, the authors argued that, under this criterion, health and life insurance should be included in the program. Second, the rate of compensation for war damage loss would be a critical problem. The authors argued that compensation could be based on the ratio of the value of surviving property to the value of property destroyed. The problem with this formula is the potential drastic change in the relative value of goods and services in the postattack economy.

Brown and Yokelson (1980) argued that a war damage compensation policy is of first-order importance for economic recovery. They contended that a number of other Federal government recovery policies are directly contingent on the method used to distribute surviving real and intangible assets:

> . . . intelligent planning for a variety of postattack economic problems cannot be completed unless there is a clear government policy on war damage compensation. (Brown and Yokelson, 1980, p. 55).

The authors maintained that a war damage compensation policy can only be arranged by the Federal government preattack and, because of the importance of damage compensation, should necessarily be included as part of the Federal government's preattack civil defense efforts.

Depending on the degree and dispersion of the attack, there will exist a highly skewed distribution of wealth in the postattack economy. Brown and Yokelson argued that there is a spectrum of possible solutions

for ameliorating the inequitable distribution of assets, ranging from a laissez-faire approach to an approach in which the government appropriates surviving assets. Dismissing the two extreme approaches as unsatisfactory, Brown and Yokelson argued for a mixed approach to war damage compensation:

> It should be readily recognized that there can be no 'pure' solution to the question of economic sharing and government controls in a postattack period. There may well be a substantial 'mix' of schemes representing various possibilities. (Brown and Yokelson, 1980, p. 53).

According to the authors, the ideal mix would include an integrated plan of direct compensation, taxation, price controls, and confiscation that would be consistent with other recovery policies pursued by the Federal government.

Since no one approach to war damage compensation can be equitable to all members of society, Brown and Yokelson envisioned an evolutionary approach to distributing surviving assets. In their view, the initial plan would be continually revised to ameliorate some of the more blatant inequities found to exist in the compensation program. The issues of equity and unfairness, however, must under no circumstances preclude implementing a compensation program.

The authors further cautioned that the effectiveness of a war damage compensation policy is contingent on the survival of the Federal government. Recognizing that the Federal government may not survive as an entity after a nuclear attack, the authors speculated that war damage compensation may become a very localized issue--administered by subnational levels of government--because of the possible fragmentation of the country into autonomous regions.

One of Quester's (1979) primary concerns with a war damage compensation program was that preattack claims to property could potentially be a significant impediment to recovery in the postattack economy. Therefore, he proposed a significant effort to document ownership of property in the preattack period. He argued that property titles should be stored in Federal or state vaults to document claims in the postattack period.

With respect to equitably administering claims to surviving property after an attack, he did not foresee adverse public reaction. What would prove to be a problem, according to Quester, is a situation in which the Federal government did not have a plan for redistributing surviving assets.

Unfortunately, Quester did not offer a specific plan for redistributing private wealth. He foresaw a political problem with announcing a specific war burden-sharing policy in peacetime because of the public's adverse reaction to nuclear war. However, he felt that the recent trend toward government involvement in risk sharing (medical insurance and natural disaster compensation, for example) could provide a sound basis for getting

> . . . the American business community and public more and more accustomed to the idea that we are already committed in advance to a sharing of burdens in the aftermath of any nuclear war. (Quester, 1979, p. 27).

One of the critical areas needing attention in the postattack period is ensuring that individual business firms are relieved of preattack burdens. Quester viewed the two most important economic problems inherited from the preattack economy as debts incurred and loans advanced prior to an attack. Quester dismissed both a moratorium on all debt obligations--a bank holiday of sorts--and a simple declaration that old debt is no longer payable. For the idea of a bank holiday, he saw it as a short-run possibility, but viewed it as inadvisable in the long run. On voiding all preattack debt, Quester believed that the policy is inequitable, confidence-shattering, and a catastrophe to holders of the debt who would rely on its income for survival.

As alternatives to these two policies, Quester suggested either a policy of inflation to lessen the value old preattack debt or guarantees by the Federal government to accept the responsibility for payment of all debts. The former proposal is simply Winter's (1966) "solvency by inflation" proposal,* while the latter is similar to the Asset Validation Equalization Corporation approach proposed by the Federal Reserve Board.

In recommending research on property rights, indemnification, insurance, and debt, Greene, Stokley, and Christian (1979) argued that these topics are the most important in economic recovery planning. They maintained that the destruction of equities (paper assets) will be more troublesome than the destruction of physical property because the earnings on which the equities are based will be stopped, the value of the equities will decline, and, in many cases, the equities will be destroyed in the attack. On the other hand, there will be windfall gains in geographical areas that suffer relatively little damage.

The authors further argued that government planners dealing with these issues face tradeoffs in the reconciliation of property rights. The tradeoffs involve questions of efficiency and equity. They wrote:

> Questions of equity are seemingly pitted against considerations of efficiency. Questions of equity appear to demand immediate and widespread redistribution of surviving assets, while questions of efficiency would appear to argue against redistribution. Other considerations argue for immediate nationalization of productive assets, among them the need of the government to insure political control and revenue. (Greene, Stokley, and Christian, 1979, pp. 39-40).

Laurino and Dresch (1980) questioned the government's planning for loss equalization. Although they recognized that policy statements have emphasized considerations of efficiency in comparison with equity, they

---

*Winter's proposal was discussed in detail in Section 6.3.

believed that more attention needs to be devoted to guiding business decisions. They argued that even if most of the decisions regarding loss equalization were left to the recovery period,

> . . . guidance is still required in peacetime with respect to the kinds of documentation and authentication of losses that will be needed to support claims and record offsetting windfall gains. (Laurino and Dresch, 1980, p. 7).

In discussing the preattack role of the federal government, Brown (1970) argued that the government must establish a war damage compensation plan, even if the plan is not totally equitable. He argued that without a plan there would be a tendency for individuals and private institutions to build up stockpiles of certain supplies--both in the preattack and postattack period. At this point, Brown argued, it would be very difficult for the authorities to relieve those stockpiles from the hoarders. Eventually, the situation would lead to violence.

In discussing the Federal government's role in establishing a free market economy, Winter (1966), stated:

> The first and most crucial problem is whether there can be a reasonably quick clarification of the question of which individuals are free to operate or dispose of what property. (Winter, 1966, p. 428).

For business firms, he called the Federal Reserve Board's Asset Validation Equalization Corporation (AVEC) an "imaginative tool" for coping with the problem of business firm bankruptcy in the postattack environment. The AVEC approach would assure the paper solvency of the economy by replacing the value of destroyed assets with a corresponding amount of AVEC bonds. The balance sheet problem of insolvency, therefore, would be ameliorated under this plan.

Many of the same issues that arise in the context of war damage compensation after a large-scale nuclear attack are applicable to compensation for damage in the aftermath of a more localized disaster, such as a flood, hurricane, or earthquake. For example, on the basis of efficiency and its contribution to a reduction in vulnerability of economic resources, Hirshleifer argued that a national system of war damage insurance in operation over a period of years with premiums based on risk of location would produce the "optimal" dispersion of resources and provide a means for compensating loss in the event of nuclear attack. Many commentators on compensation for damage caused by floods have argued--in a manner similar to Hirshleifer--that a national system of flood insurance with premiums based on risk of location would accomplish something similar in that the premiums would provide incentives for location or relocation to areas less likely to be damaged by floods. It would also provide a compensation mechanism that does not rely on federal government appropriations for disaster relief.

There is no area in the relatively sparse literature on the economics of natural disasters that has received as much attention as the question of Federal aid versus disaster insurance to compensate for

losses of life and property. Kunreuther and Fiore (1966) argued for a comprehensive system of private insurance for all types of natural disasters. Coverage for every natural disaster would be included in one single policy. They argued that three types of insurance systems should be considered for implementation. First, the policy could be made compulsory by the Federal government. Premiums would be based on the risk of living in certain areas of the country. Second, disaster insurance premiums could be included as part of a mortgage and handled jointly by the mortgage company and the insurance company. Third, coverage for disasters which the private sector has not historically insured--flood damage, for example--could be included in the extended coverage clause of insurance policies. The authors conceded that all of the proposals have disadvantages, but they are alternatives to be considered in the place of relying on the appropriation of large sums of Federal aid to ensure that victims of a disaster, not covered by private insurance, are compensated for their losses.

Kunreuther (1968) summarized the economic effects of a comprehensive system of disaster insurance:

> Comprehensive disaster insurance should lead to a much more efficient allocation of resources in the future and eliminate the inequitable effects of the current system of federal aid to the private sector. By forcing individuals to bear the full risk of living in an area where previously they were subsidized after experiencing bad luck, we are suggesting a definite structural change in policy. (Kunreuther, 1968, p. 162).

In a later study devoted to the short- and long-term effects of the 1964 earthquake in Alaska, Dacy and Kunreuther (1969) again called for a comprehensive system of disaster insurance:

> Some form of disaster insurance based on risk provides a means of protecting individuals before the unexpected happens, thus obviating the need for large-scale Federal relief. At the same time, unwise development of disaster-prone areas should be curtailed. (Dacy and Kunreuther, 1969, p. 230).

They offered three primary reasons for a disaster insurance system. First, Federal aid is contingent on the classification given the area--"disaster area," for example--and any special congressional legislation enacted in the aftermath of the disaster. The system is inequitable. Second, the system of disaster aid frequently benefits the gambler at the expense of the cautious individual. Third, Federal aid does not encourage relocation away from disaster-prone areas. Therefore, the present disaster compensation approach has the tendency to encourage more Federal aid in the future.

Kunreuther (1973) argued for a comprehensive system of disaster insurance by attempting to show from analyses of the San Fernando earthquake in 1971, the Rapid City flood in 1972, and Tropical storm Agnes in 1972 that disaster insurance is better for both the homeowner and the Federal government than direct Federal disaster relief. Kunreuther viewed the reliance on Federal assistance in the form of low-interest

loans and grants as providing the wrong incentives for alleviating the problems of damage compensation in the aftermath of natural disasters:

> The cost of repairing damage from natural disasters is now being treated as a public responsibility. The general tax-payer is being burdened with an increased role in the financing of recovery for those caught by misfortune despite the availability of insurance, of sites in less hazard prone areas, and of construction methods that will reduce losses. (Kunreuther, 1973, p. 1).

Although Kunreuther embraced the general concept of disaster insurance, one of the problems he saw in implementing a program would be the question of whether coverage is compulsory or voluntary.

Using another approach, Kunreuther (1978) reported the results of interviews with 2055 households in 13 states prone to floods and 1006 households in California that are prone to earthquakes. The purpose of the interviews was to ascertain why so few homeowners purchased flood or earthquake insurance when it was available. Kunreuther concluded:

> Our results strongly suggest that the consumer is the source of market failure. It thus may be necessary to substitute other institutional mechanisms for the free market if individuals are to be protected against the consequences of low probability high loss events. (Kunreuther, 1978, p. 244).

Baumann and Sims (1978) also attempted to ascertain why individual households do not participate in private flood insurance programs. To this end, they undertook a study of the adoption of flood insurance in two flood-prone communities in Texas. The results of their research suggested that three factors are important in flood insurance adoption:

> The insured homeowner is he who has suffered damage from a flood, who enjoys a relatively higher social class position, and who is internally-oriented, that is, feels that the effects of the future on him are determined by his own current behaviors. (Baumann and Sims, 1978, p. 195).

In assessing research on natural hazards, White and Haas (1975) also argued for a system of disaster insurance. However, they cautioned against developing a system that has improper incentives embodied in it:

> It is abundantly plain that insurance, if provided on a wholly subsidized basis, or on a basis that does not distinguish degrees of risk, would exacerbate rather than reduce the nation's difficulties with natural hazards. An insurance plan with uniform premiums which took no account of differences in risk would encourage continued or greater occupation of hazardous areas. A system which would be so heavily subsidized that the individual policy owner regards the premiums as insignificant would also have the effect of enlarging the property and population subject to hazard if premiums were sub-

stantially below subjective expected losses. (White and Haas, 1975, p. 218).

A number of conceptual studies have also been undertaken on various aspects of the disaster damage compensation issue. Lewis and Nickerson (1984), for example, examined optimal levels of self-protection from disasters, considering risk and the technology employed to protect against them. Li, Page, and McKelvey (1984) examined the dissemination of price information by insurance companies as a measure of information related to consumers on natural hazards. Marshall (1984) examined the optimal level of insurance to protect against natural hazards.

6.6. HISTORICAL ANALOGUE: GERMANY IN THE AFTERMATH OF WORLD WAR II

The purpose of this section is to discuss the impacts of economic control mechanisms used in reconstructing Germany in the aftermath of World War II. Although there is no perfect historical analogue for both the scale of destruction and disruption likely to be experienced in the aftermath of a nuclear war, it is anticipated that some of the economic problems encountered in reconstructing a severely damaged economy such as Germany will surface in a postattack environment. Examining these problems--and the approach used to resolve them--can provide a frame of reference for postattack recovery planning. While the experiences of other nations in the aftermath of a large-scale disaster may be relevant to the discussion, it was felt that Germany faced a wide enough array of economic problems in the aftermath of World War II to serve as the most appropriate analogue.*

The economic policy pursued by Nazi Germany during the course of World War II and by the Occupying Powers after the war was repressed inflation. During the years immediately preceding the outbreak of World War II and during the conduct of the war, economic decisions in Germany were increasingly centralized. All production decisions were controlled by agencies of the government. An elaborate system of controls was established to allocate the raw materials used in manufacturing. Investment was also controlled by the central authority and investment in economic activity not related to the war effort was disallowed by the central administration. Moreover, through a system of financial controls, the private sector was virtually forced out of capital markets, relegating the financing of capital expansion to retained earnings. This elaborate industrial control mechanism was supplemented by a comprehensive system of price controls enacted in November, 1936. In essence, all

---

*Many other authors have argued that a study of prior disasters can be very beneficial in illuminating economic problems that may arise in a postattack environment. The participants in Panel D of Project Harbor [National Academy of Sciences (1963)], for example, argued that, besides postwar Germany and Japan, divided Italy behind the lines could be used as analogies also because in the three situations ". . . the problem was to put the pieces of a shattered mechanism together again, amidst damages, social disruption, and general confusion." (National Academy of Sciences, 1963, p. 44).

prices for goods and services were placed under the jurisdiction of the central authority.

The economic policies pursued by the Nazi regime during the war led to a dramatic decline in per-capita consumption, caused by diverting resources into war-related production, and an increase in liquidity in the economy. Turek (1969) estimated that real per-capita consumption in Germany declined to an index rating of 70.5 in 1944 from a base-year level of 100 in 1938. Turek also estimated that purchasing power accumulated during the war years led to a situation in which in 1944 it was 5.7 times greater than current private spending. This contrasts with the experience of the U.S. economy, where liquid assets only accumulated to 1.3 times current spending over the same time period.

Eucken (1948) argued that a centrally directed economy in Germany both prior to the war and during its duration did not result from deliberate German planning, but was a phenomenon that evolved out of the full employment policy pursued by the Nazi regime in the 1932-1933 period. That policy was manifested in an expansion of the money supply, which eventually led to the imposition of direct controls on prices in 1936 to thwart inflationary pressures. As war became imminent, centralized control of the economy expanded because of the desire to direct an increasing amount of economic resources into armaments production. Although centralized control characterized the German wartime economy, economic resources were owned by the private sector. On the functioning of the wartime economy, Eucken observed:

> The interesting point is that in Germany the means of production remained predominantly in private ownership, and farms and factories alike continued to belong mainly to private individuals and companies. But the private owners could only dispose over their means of production to a limited extent. There was widespread requisitioning of industrial stocks, which were only released for definite purposes consistent with the central plan. We can say, in fact, that for the economic process as a whole, it was not the plans and actions of individual businesses and households that were decisive, but the plans and orders of the central authorities. (Eucken, 1948, p. 80).

The cessation of hostilities in Europe and the Potsdam Conference held in the summer of 1945 led to reorganization of Germany into four zones, each of which was administered by one of the allied victors. Three principles were to underly the functioning of the German economy during reconstruction. First, war-related production was to be incapacitated. Second, the German standard of living was not to exceed that of other European nations, with production limited to approximately three-fourths of the 1936 level. Finally, countries that were damaged by Germany were to be compensated from German national wealth. The economic principles for German recovery were, however, abdicated by Britain and the United States in July of 1947 because of the excessive drain placed on those two nations in supporting the German recovery.

With respect to economic organization and stabilization of the economy, the occupying powers continued the elaborate system of controls that were used by the Nazi regime during the war. The system of rationing was continued. Food and raw material coupons were issued to consumers and manufacturers, respectively. The system of wage and price controls was continued. However, in many respects, the system was more rigid than that imposed by the Nazis during the course of the war because price adjustments were not allowed if they directly affected wage levels. Mendershausen commented on the implementation of price controls across the four occupation zones:

> Within the various occupation zones, the implementation of the price stop policy showed much similarity in form but variation in substance. The Russians used the price squeeze as a means of making private business unprofitable. They exempted from German price law the Soviet corporations that they set up in their zone. In the American zone, price policy was dominated by a 'hold-the-line' spirit in the absence of any strong business pressure. The French followed an equally rigid approach while the British vacillated between a Treasury approach of curing inflationary pressure by price increases and a political preference for price-wage stability, the result being a somewhat laxer price stop. (Mendershausen, 1949, p. 648).

Under this price control policy, prices were established by fiat and generally no attempt was made to adjust the legal ceiling prices to realistic levels determined by economic forces. The system of price ceilings was quite effective. Mendershausen observed:

> Price control during the first three years of occupation was surprisingly effective. There was a great deal of evasion; but the bulk of the goods changed hands at legal or nearly legal prices. (Mendershausen, 1949, p. 651).

The consequences of the economic policies pursued by the occupying powers were exacerbated by the excess amount of liquidity in the German economy. There were two economic forces at work. First, there was pent-up demand manifested in excess purchasing power and, second, because of the rigidity of controlled prices, relative prices were not set properly. In this set of circumstances, there were no incentives to produce at realistically low price levels and, consequently, there were shortages of goods. Because of the policies pursued by the occupying powers, it has been estimated that between 30 and 40 percent of the industries in Germany could not price their output at a level sufficient to recover costs by 1946.

In contrast to other experiences with price controls, there was no attempt to adjust prices to reflect actual production costs. Typically, under a system of price controls, legal prices are adjusted in an attempt to reflect market realities. In Germany, both the price structure and price levels established in 1936 were virtually carried over into the postwar period.

The mismanagement of the German economy in the immediate aftermath of the war had serious repercussions for economic performance. Turek concluded:

> . . . given the acute scarcity of real goods, the combination of an excess supply of liquid assets resulting from the repressed inflation policy of the Nazis and a rigid system of price and wage controls produced intolerable conditions. The economic controls obstructed the spending of these excess liquid assets; however, they failed to accomplish the more difficult task of providing adequate incentives for work and production for monetary reward. (Turek, 1969, p. 83).

There were three consequences of this economic control system. They included disincentives to work and produce, abandonment of the monetary system, and leaving the cities to obtain food. Each of these consequences will be discussed in turn.

First, there was a disincentive both to work and produce essential commodities. The policy of repressed inflation in concert with high taxes on earned income provided little incentive for an individual to offer his labor services. This led Turek to conclude:

> Coupled with this severe shortage of consumer goods was a plethora of money. Most people had more money than could be spent on available goods, and few expected production levels to rise rapidly enough in the near future to absorb these excess funds. Hence, there was little incentive to work in order to add to money stocks. An individual could improve his standard of living by working only long enough to acquire the money needed to obtain official rations and then by going absent from work to engage in barter transactions, to plant a garden, to repair his home, and so forth . . . In addition, the Allied policy of taxing earned income heavily while leaving money assets untouched destroyed the public's incentive to work for monetary payment. (Turek, 1969, p. 81).

In contrast to the Nazi regime's dedication to keeping controlled prices consistent with rising costs of production, the Allies maintained a very rigid system of price controls to hold down the level of wages. The inflexibility of prices in concert with other economic factors had a detrimental effect on production:

> . . . costs were rising sharply owing to declines in the productivity of labor, scarcities of raw materials, war damage, and a substantial shift in the composition of output as war production ceased. As a result many firms were unable to cover costs at official prices. This created a situation in which the more important a commodity was to the community, the less likely it became that it could be profitably produced. (Turek, 1969, p. 81).

Second, there was an abandonment of money as the sole medium of exchange. Although it was noted above that the system of legally imposed

prices was effective in the sense that few transactions violated the price system, new forms of exchange evolved which superceded the legal prices. Mendershausen observed:

> . . . in the midst of currency, supply and demand conditions that would certainly have produced price inflation in a market economy, there remained a fairly high degree of price discipline and stability under price control. But the economic incongruity of the situation produced changes in the methods of distribution, a limited black market and a widespread system of reciprocal exchanges of goods and services. These changes took the substance out of the price system and tended to make it a hollow shell. (Mendershausen, 1949, p. 652).

The black markets that arose as a consequence of the system of controls were not the basic conduit for exchange during the reconstruction period. Mendershausen estimated that less than 10 percent of transactions were cc ummated in black markets; that is, transactions at prices or price equivalents above the legal ceiling prices. Transactions in black markets were primarily for finished products at prices that Mendershausen estimated were, on average, 50 to 75 times greater than the legally imposed price levels. In general, business firms only engaged in black market transactions in emergencies. Households also did not generally offer labor services in the black market.

However, another form of exchange that superceded the legally imposed price system evolved for private transactions. That system involved bilateral exchange for essential goods and services. The reason for its evolution as the primary means of exchange was that certain goods and services could not be obtained for money alone but could only be obtained with an appropriate amount of other goods and services.

In industry and trade, a form of bilateral exchange--termed compensation trade--was one of the primary means of exchange. Estimates of the volume of transactions under this system have ranged from a third of all transactions to more than 50 percent. Lutz (1949) characterized the system as follows:

> . . . individuals and business firms acquired most of the commodities they wanted by exchange against commodities they had to offer, and a whole series of exchanges were sometimes necessary to obtain the desired commodity. Every firm had specialists, called 'compensators', on its staff. If, for example, cardboard for packing was needed, the compensator might be obliged to barter the plant's own products for typewriters, the typewriters for shoes, and the shoes for cardboard. All this was not only illegal but involved tremendous costs. In one case known to the present writer five long trips by a compensator were required to obtain a case of special varnish, whereas formerly a postcard dropped into the post box would have been sufficient. (Lutz, 1949, p. 122).

As Mendershausen pointed out, the system of bilateral exchange was not limited exclusively to pure barter transactions. Money entered some

of the transactions as both a standard of accounting and a means of payment. Mendershausen provided an example:

> For instance, the going rate for the widespread bilateral exchange of cement for coal was one ton of coal for one ton of cement. At legal prices, one ton of coal was the equivalent of one-half ton of cement. The balance due the cement producer at legal prices would usually be settled in money. That was for bookkeeping purposes chiefly. (Mendershausen, 1949, p. 656).

The system of bilateral exchange had the expected effects on industrial output. Turek summarized the effects:

> The necessity of devoting large amounts of time to arranging bilateral swaps further reduced productivity and raised production costs. At the same time, it resulted in distortions in the composition of output that favored unessential goods, thereby intensifying the scarcity of necessities. (Turek, 1969, p. 81).

Bilateral exchange was not limited to the industrial sector of the economy, but also characterized relationships between management and labor. Similar to the relationships in industry, laborers would not offer their services unless they were compensated at least partially in kind for their services. The goods received as a result of productive activity were, in turn, used as bargaining elements in further barter or bilateral exchange transactions. As discussed above, this was partially a manifestation of the excess liquidity in the economy where goods--and not the medium of exchange--were in short supply.

Third, related to the other effects, Germany experienced what Hirshleifer (1963) has termed the "generalized disaster phenomenon" that is characterized by the "trekking" of people living in urban areas to the countryside in search of food. Based on analysis of economic reconstruction following several historical disasters, Hirshleifer identified this phenomenon as a common characteristic resulting from ill-advised economic policies pursued in the aftermath of disasters. The basic feature of the phenomenon is a scarcity of food attributable to the disincentive to produce it. While governments may adopt different policies to cope with the phenomenon, the incentives built into the system encourage abandonment of urban areas in favor of food-producing regions. In postwar Germany, a system of quotas for mandatory delivery of food to cities was established. However, the system was not effective and did not prevent pervasive "trekking" to the countryside for food bartering. Mendershausen summarized the German experience:

> The city people hiked to the villages with an assortment of hardware, textiles, tobacco and personal possessions and bartered them for food. In this trading, money played almost no role at all. City people also worked as farm helpers for the food and whatever living quarters were available in the crowded villages. (Mendershausen, 1949, p. 657).

Economic controls were terminated in June, 1948 at which point an economic reform program was initiated. Securities such as bonds and mortgages were converted at a rate of 10 Reutschmarks--the old unit of exchange--to one Deutshce mark--the new unit. For currency, demand deposits, and savings, the exchange rate was more than 15-to-1.* The effect of the reform was to liquidate the excess purchasing power in the economy. For international trade purposes, the exchange rate of the Deutsche mark was pegged at $0.30 in terms of the U.S. dollar.

In conjunction with the currency reform, the authorities relaxed a number of other economic controls. Price and rationing controls were abandoned or substantially relaxed. Business and personal taxes and property taxes were reduced.

The effect of the monetary reform was immediate. The monetary system was reestablished and goods reappeared in stores. The combination of less money available for transactions on the part of consumers and the need for currency by producers led to both the offering of more goods in the market and the incentive to work on the part of the population. Economic growth after the June 1948 reforms was astonishing. The increase in production from June 1948 to December 1948 was estimated to be more than 50 percent in the bizonal area occupied by Britain and the United States. The monetary reform in concert with the abolition of most price controls by November 1948 reestablished an effective system of relative prices that provided proper market signals for production.

Lutz summarized the effect of the June 20, 1948 currency reform:

> The immediate effect of the reform was startling. On June 19th, a Saturday, not a single article could be seen or had in the retail shops. On June 21st the shops were full of goods: housewares, textiles, cameras, etc. These stocks had been withheld, because with the knowledge that the reform was imminent, no trader wanted to sell against RM and be left with RM balances. The supply of goods in the retail shops, which had never been large since the end of the war, had completely dried up in the months preceding the reform. The scarcity of money in the first week forced the hidden inventories on to the market, and the dramatic change in the supply of goods was the main reason why the reform found general acceptance among the population at least in the beginning . . . The currency reform had created a new atmosphere of great expectations, an atmosphere in which other measures were willingly accepted. (Lutz, 1949, p. 132).

It must be emphasized that a number of factors other than currency reform, relaxation of controls, and tax reform contributed to the re-

---

*These exchange rates under the German currency reform are somewhat of an oversimplification. However, a detailed discussion of the specifics of the reform are beyond the scope of this overview. For a detailed discussion of the reform--and the role of banking institutions in that reform--the interested reader is referred to Lutz (1949).

vival of the German economy. Lutz argued that increased aid through the Marshall plan was as a contributing factor. Other authors have provided similar arguments. However, after reviewing German economic recovery after the currency reform in the context of other events in the German economy, Hirshleifer concluded:

> . . . the analysis here indicates that social and political disorganization was not too significant as an independent factor after the crisis of 1945, while the economic disorganization caused by the lack of an effective monetary mechanism persisted until the reform. (Hirshleifer, 1963, p. 111).

7. ASSESSMENT OF RESEARCH ON POSTDISASTER ECONOMIC RECOVERY

7.1. INTRODUCTION

The purpose of this chapter is to assess prior research on postdisaster economic recovery which was reviewed in Chapters 2 through 6. Perhaps the most salient characteristic of prior research is the relative scarcity of substantive work on the institutional infrastructure of a postdisaster economy. Also, in comparison with disasters resulting from natural phenomena, the literature has emphasized economic aspects of recovery from generalized disasters.

Analysis of the economic effects of natural disasters on the the physical infrastructure of local economies has generally proceeded along two courses. First, in the majority of studies, prior disasters have been analyzed using historical time series data to ascertain both the short- and long-term effects of the disasters on local economies. Typically, aggregate economic indicators--employment and retail sales, for example--have been analyzed for a period of time prior to the disaster, during the period immediately following a disaster, and, for the long term, over a number of years to determine if the disaster had any perceptible influence on the economy. Second, economic models have been used to simulate the effects of hypothetical disasters.

In general, the results of the studies of geographically localized disasters have shown that there are no long-term effects of the disasters on regional or local economies. For the short term, the studies have generally shown that the disaster provides a stimulus to the local economy.* In an econometric simulation study of the long-term economic impact of a hypothetical earthquake in the Charleston, South Carolina metropolitan area, for example, Ellson, Milliman, and Roberts' (1984) conclusion is typical of the conclusions in studies of the long-term effects of natural disasters:

> What is clear is that the health of the regional economy is determined more by the assumptions one makes about the national (exogenous) growth factors driving the regional economy than by the disruptive effects of an earthquake whose severe effects are largely temporary and tend to diminish over the longer run. (Ellson, Milliman, and Roberts, 1984, p. 570).

Moreover, in an analysis of statistical time series data to ascertain the economic effects of the 1964 earthquake in Alaska, one of Dacy and Kunreuther's conclusions reflects the general results obtained from analyses using aggregate economic indicators to measure the effects of natural disasters:

---

*The only prominent exception to this general statement on short- and long-term recovery from geographically localized disasters is a potentially devastating earthquake in California. For simulations of the performance of the regional economy in the aftermath of a hypothetical earthquake in California, see Cochrane (1975) and Munroe and Ballard (1983).

In fact, a disaster may turn out to be a blessing in disguise. Aside from the economic boom that often follows because of the large amount of reconstruction, there is an opportunity for commercial establishments and homeowners to improve their facilities. (Dacy and Kunreuther, 1969, p. 168).

The emphasis in the literature on institutional issues associated with disasters resulting from natural phenomena has been on damage compensation in the aftermath of a disaster. Concisely, the majority of contributors to the literature have argued that a comprehensive system of disaster insurance is much preferred to the ad hoc approach that has historically been used in compensating for disaster-related losses.

Because the literature emphasizes economic aspects of recovery from a hypothetical generalized disaster resulting from a nuclear attack, the remainder of this assessment will be focused on recovery from that type of disaster. In recent years, several other authors have provided an assessment of research on recovery from nuclear attack in various degrees of detail. For example, Greene, Stokley, and Christian (1979) analyzed six obstacles to recovery from nuclear attack in the context of providing a foundation for a research program to address some of the difficulties that most likely will be encountered in a postattack economy. With respect to research on a new master plan for economic recovery, the authors concluded:

It [the plan] must recognize and provide alternatives for quickly overcoming the many possible problems that could complicate restoration of a functioning economy--problems such as the need for currency reform, reestablishment of property rights, repair of the banking and judicial systems and a host of others. (Greene, Stokley, and Christian, 1979, p. 34).

Similarly, Laurino and Dresch (1980) called for a new program to address postattack recovery needs:

A review of past research efforts and plans supports the conclusion that a primary prerequisite for progress would be the establishment of a program of significant size over a considerable period. Coincident with the start of such a program, or as a first step, would be a coordinated interagency commitment to a serious effort and to general policy guidelines concerning levels of politically feasible preparedness measures and well-defined positions on loss equalization, degree of centralization of recovery management, and similar broad issues. (Laurino and Dresch, 1980, p. S-8).

In many respects, the remainder of this chapter is both an amplification and extension of the work of Greene, Stokley, and Christian and Laurino and Dresch. That is, while these recent studies have called for research to eliminate some of the gaps in current postattack recovery planning, the present chapter provides a detailed assessment of prior research that has, to some degree, shaped the current recovery plans.

The presentation in the remainder of this chapter is hierarchical in the sense that the following section provides a broad overview of the functioning of the economic system, along with a discussion of the aspects of that system that have been addressed in the literature. In the remaining two sections, the discussion will turn to more specific issues related to research on the physical and institutional infrastructures in the aftermath of a generalized disaster.

7.2. AN OVERVIEW OF POSTDISASTER RESEARCH IN THE CONTEXT OF THE U.S. ECONOMIC SYSTEM

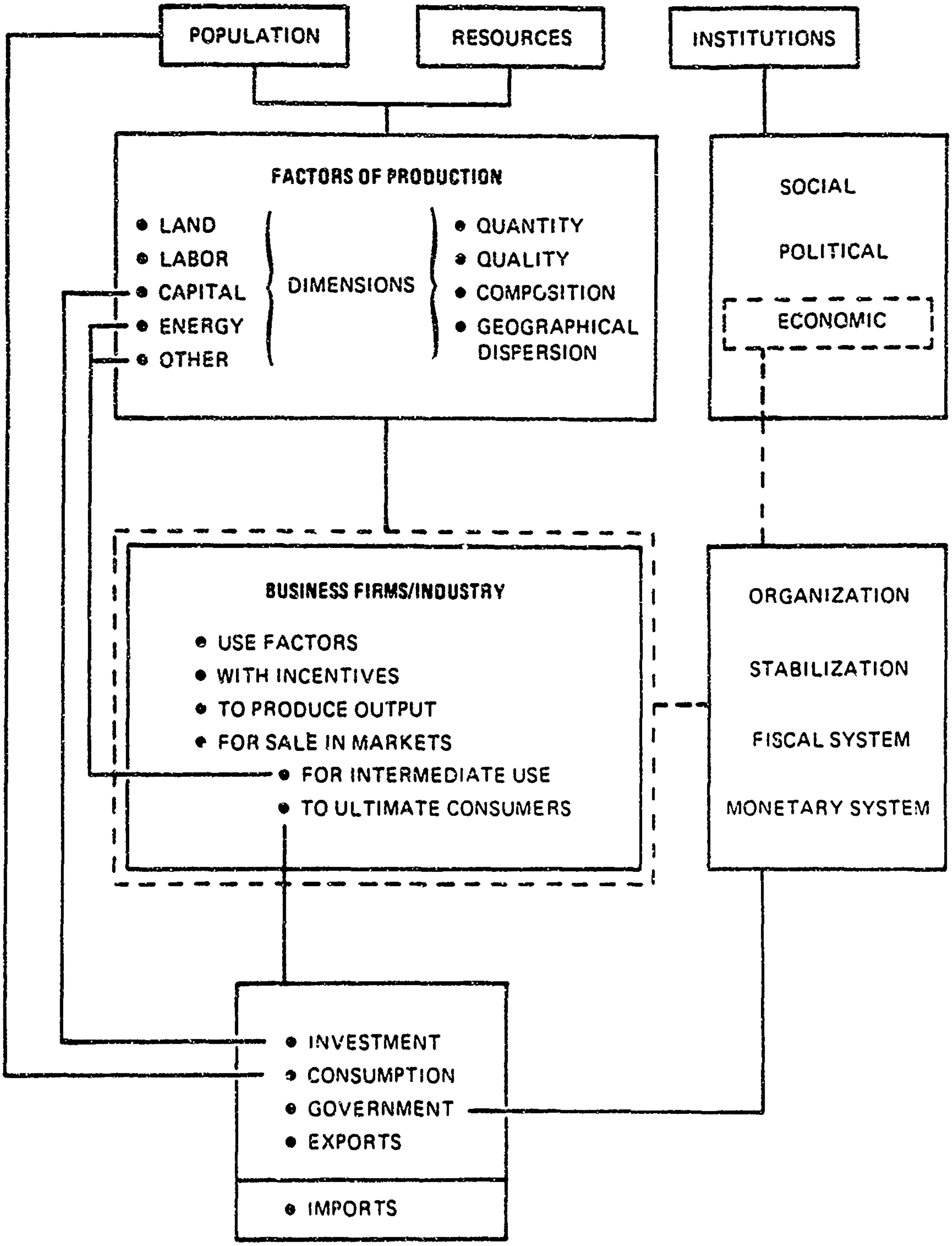
Figure 7.1 provides a somewhat simplified characterization of the U.S. economic system. The framework established in Figure 7.1 emphasizes the relationship of various components of the system to one another and does not characterize the flow of goods or money through individual sectors of the economy. The framework is presented as a convenient means to illustrate the nature and extent of research that has been undertaken on various aspects of the postdisaster economy.

The uppermost echelon of the figure--population, resources, and institutions--provides a highly aggregated characterization of the sources of inputs into the economic system. Disaggregating, population and resources comprise the inputs into the production process or, technically, factors of production. These factors have a number of dimensions, including their quantity, quality, composition, and geographical dispersion. Institutions that have evolved to coordinate or provide an environment for productive activity can be generalized into those related to social, political, and economic aspects of the nation. Factors of production used by industry, final demand for goods, and economic institutions in the third and fourth echelons of Figure 7.1 are the components of the economic system around which the research reviewed in the previous five chapters was organized--namely, the physical and institutional infrastructures.

Factors of production are harnessed by business firms which produce output both for sale in intermediate markets and to ultimate consumers. The behavior of business firms is guided by a profit motive and, at least conceptually, producers are assumed to maximize profits--or, alternatively, minimize costs--under a system of incentives provided by institutional arrangements. Because of the focus on economic recovery, the <u>economic</u> institutional infrastructure has been emphasized in Figure 7.1. Economic institutions are characterized by the organization of the economy, the stabilization policies pursued by the Federal government, a fiscal system at all levels of government, and a monetary system established and maintained by the Federal government.

Output of the economy for ultimate consumption is used to satisfy consumer needs, investment needs, purchases of the government, and production for export. Investment goods are used as an input for production. The characterization of imports in Figure 7.1 is an oversimplification because, in many sectors of the economy, imports play an important role as inputs in the production process. Imports are also used to satisfy final end-use demand. In Figure 7.1, they are presented sim-

Figure 7.1
Schematic Representation of the U.S. Economic System



plistically to prevent complication of the figure and to characterize gross output in the economy. That is, the sum of the first four items in the final echelon of Figure 7.1--investment, consumption, government, and exports--net of imports provides a measure of gross national product in the economy.* Production for intermediate use in Figure 7.1 is classified broadly as energy and other materials used in production.

The most important component in Figure 7.1 is the conduit through which productive activity occurs--the business firm and, after aggregation, the industry. Conceptually, a system of relative prices--determined, in general, by the interplay of market forces--determines both the selection of inputs used in production and the level of output that is produced.

For the selection of inputs, an individual producer is confronted with an array of input choices, given the constraints imposed by technology. The selection of inputs is determined by their relative prices. For example, the determination of the relative use of capital versus energy in the long run--to the extent that these factors are substitutes for one another--is determined by the relative price of capital to energy.

There are various institutions built into the system to guide decentralized decisions on both the level of investment and production that are consistent with the level of demand. For products whose price is volatile from period to period, organized futures markets have been established to provide an indication of future price levels to producers in the current period that guide investment decisions and, hence, future output levels. Perhaps the best examples of markets subject to this type of price volatility are markets for agricultural commodities where the market-determined price fluctuates more freely from year to year relative to the prices of other products. For products whose price is not subject to such extreme volatility from period to period--durable goods, for example--additions to capacity and, therefore, expansion of output are made incrementally, based on the expectation of relatively stable real prices. In all cases, financing of capital expansion, current operations, or entry into new markets is facilitated by an organized system of capital markets.

The entire system operates in an institutional environment that has evolved over time. The fundamental feature of the system is its market orientation where decisions on resource allocation are made on a decentralized basis. Decentralized decisionmaking is guided by a fiscal and

---

*The representation of Gross National Product in Figure 7.1 is a simplification of the method used to calculate this measure in the social accounting system. While the general scheme of aggregating all final expenditures--investment, consumption, government purchases, and production for export--net of imports is consistent with the determination of aggregate output, investment expenditures are in reality comprised of capital formation, housing construction, and changes in inventories. For this presentation, the latter two categories of investment have been ignored.

monetary system. In the event that the government needs to redirect economic activity, it has a number of options available to "push" the economy on a course it has chosen without the use of direct intervention. A good example of this is use of the tax system to provide incentives for specific types of economic activity. More drastic measures involving direct government resource allocation have occurred during wartime where an elaborate system of controls, allocations, and rationing have been imposed to redirect output to war-related industries.

To varying degrees, studies of the postdisaster economy which were reviewed in the previous two chapters have addressed every component of the economic system as depicted in Figure 7.1. Highly aggregated studies of the national economy have assessed the vulnerability of national resources (the first echelon of Figure 7.1)--population, resources and institutions. In these studies, data bases on the geographical dispersion of national resources have been developed and hypothetical nuclear attacks have been imposed to determine the effect of the disasters on the surviving population, resources, and institutions. Resources have typically been measured as industrial capacity and institutions have been measured in terms of private and public decision-makers--corporate management and government administrators.

The majority of studies of postattack recovery have concentrated on surviving factors of production in the aftermath of hypothetical nuclear attacks. The research has proceeded along two fronts. First, individual industries have been scrutinized to determine potential problems in recovery. The studies have involved determining the availability of inputs after a hypothetical attack; the physical vulnerability of components of the industry to nuclear weapons effects; the vulnerability of industries to a rapid shutdown of operations; estimation of potential postattack demand for the industry's output; and substitution possibilities both between inputs and production processes. In many of the studies, the potential for substitution has encompassed conventional substitution possibilities that characterize the preattack economy as well as the potential for nonconventional substitution.

Second, resource assessments and economic models have been used to determine the vulnerability and viability of both national and subnational economies in the aftermath of hypothesized nuclear attacks. The approach used in resource assessments has been to impose a hypothetical attack on the national or subnational economies and to evaluate the dimensions of the surviving factors of production--quantity, quality, composition, and geographical dispersion. Inferences were then drawn on the potential for economic recovery. Similarly, the effects of a hypothetical nuclear attack have been used to reduce factors of production in economic models in simulating the effects of the attack on the national and regional economies. Typically, emphasis has been placed on simulating the postattack per-capita output of the economy. The und rlying assumption in the modeling studies was that economic institutions will be established or reestablished to provide the proper environment for productive activity.

Although all of the economic institutional issues depicted in Figure 7.1 have been addressed in the literature, no comprehensive and con-

sistent proposal has emerged to provide policy guidance for reestablishing economic institutions in the aftermath of a nuclear attack. Problems with organization of the postattack economy and stabilization measures have received the most attention. Problems associated with the fiscal and monetary system, capital markets, and incentives have been addressed, for the most part, in terms of problems they pose for recovery.

7.3. PHYSICAL INFRASTRUCTURE

The literature on the physical infrastructure of the economy in the aftermath of a large-scale nuclear disaster can be viewed as attempting to answer two broad questions:

1. Do resources survive in sufficient quantities to accommodate economic recovery at a national or regional level after a hypothetical disaster?

2. What are the physical impediments to economic recovery?

In summary, three broad approaches have been used to assess the recovery potential of the national economy and regional economies and the potential impediments to recovery: (1) economic resource assessments; (2) formal economic models; and (3) individual industry studies.

National or subnational economic resource assessments have ranged from simple analyses of surviving population, labor, and industrial capacity in the aftermath of hypothesized nuclear attacks to relatively detailed analyses of the surviving labor-capital composition. The results of the more general resource assessments--percentage of preattack population, labor force, and industrial capacity surviving an attack, for example--were used to draw inferences about the capability of the region under examination to recover from the attack. In general, the results of the studies showed that prospects for economic recovery from the hypothetical attacks were favorable. Since they did not generally provide any indication of the ability of the surviving managerial capacity to harness these resources into a viable recovery mechanism, the results can at best be used to identify problems with surviving physical resources that may arise in a postattack economy. The results do not provide a definitive statement on recovery potential.

With respect to the use of economic models to simulate the performance of the postattack economy under hypothetical attack scenarios, an approach that lends itself well to isolating problems of potential significance for economic recovery is input-output modeling. Input-output models cast in a linear programming framework have been used extensively to identify bottlenecks that could potentially impede the production of both intermediate inputs or final demands in the postattack economy.

The level of aggregation across individual industries in input-output studies was determined by information on the interindustry production coefficients in the economy at the time the studies were under-

taken. The earliest studies of the postattack recovery potential of the U.S. economy were highly aggregated. For example, Clark's 1958 study of the recovery potential of the economy was based on nine sectors [see Kahn et al. (1958)]. Ensuing studies using the input-output approach were disaggregated in accordance with information on interindustry relationships. A description of the models and a discussion of simulation results were presented in Chapter 3.

While the results of simulation studies using an input-output approach generally have showed that the potential for economic recovery is favorable, the input-output approach has a number of limitations that are especially important in the context of simulating postattack recovery potential. First, the input-output coefficients reflect peacetime production relationships. Their use for simulation of the postattack economy does not reflect severe disruptions in economic relationships caused by both the absolute and disproportionate destruction of resources. Second, economic activity within any individual aggregated sector is assumed homogeneous. That is, all products and processes are assumed the same. Third, and related to the second assumption, all activity within an individual sector is assumed completely substitutable within that sector and, moreover, no potential substitution of products or processes across different sectors is accounted for. Finally, at least for national models of the postattack economy, the production relationships are aggregated geographically which masks many of the important interregional problems that may arise in the postattack economy. Perhaps the most prominent of these problems is transportation across geographical regions.

Many of the potential problems in the postattack economy that are masked by input-output studies have surfaced in studies of individual industries. In a recent study of the aluminum industry, for example, Block et al. (1977) examined, among other issues, the relevance of a relatively disaggregated, 367-sector, input-output representation of the U.S. economy for analysis of postattack problems in the aluminum industry. With respect to input-output tables, the authors concluded:

> A review of a highly disaggregated set of economic input/output coefficients (367 sectors) indicated input sectors with low dollar values but without suitable substitutes. Therefore, performing a postattack sensitivity analysis to determine the relative importance of ingredients for rebuilding based upon input/output coefficients (in other words, relative price) is meaningless. In addition, capital equipment is included only at a gross level of aggregation and at typical annual depreciation levels--not at plant replacement levels. Furthermore, some supplies necessary to normal operations (such as refractory brick) are not included in the tables. (Block et al., 1977, p. 24).

A number of other in-depth studies of individual industries illuminated problems for economic recovery that cannot be captured in input-output studies. The work by McFadden and Bigelow (1966)--the steel and petroleum refining and petrochemicals industries--and Tate and Billheimer (1967)--the aluminum industry--on the detrimental impact asso-

ciated with a rapid shutdown of these industries has important implications for postattack recovery. Van Horn and Crain's (1975) study of the process control industry from both a supply and demand standpoint underscored the potential problems with process control in an industry where, from a supply standpoint, important inputs are derived in large measure from two regions of the country and where, from the standpoint of demand, rapid technological advances potentially increase the vulnerability of control measures in industries using electronic process control devices.

A study by Miller and Stratton (1980) on the petroleum industry provided one of the many substitution possibilities that are feasible in a postattack economy. An expedient crude oil unit to produce diesel fuel could substantially reduce the amount of time that it would take to make diesel fuel available. Similarly, the conventional and nonconventional substitution possibilities for electric power described by Foget and Van Horn (1969) could potentially ameliorate some of the electric power problems in a postattack economy. Many of the other studies of individual industries that were presented in Chapter 5 illuminated problems and potential solutions for various industries in the postattack economy that are beyond the capability of input-output models to address.

As the state-of-the-art in economic recovery modeling progressed, many analysts saw the need to relax the assumption of fixed production coefficients. A refinement in the fixed production technology approach was the introduction of production functions that relate output in individual sectors to the use of capital and labor. More recent refinements include the use of endogenously determined input-output relationships which are based on the level of surviving resources after a hypothetical attack on the system. Moreover, recognizing the deficiencies inherent in simulating the performance of the economy on the basis of surviving physical resources alone without consideration of economic institutions, the most recent attempts at modeling the postattack economy have used a system dynamics approach in which managerial, fiscal, monetary, and psychological elements impinging on economic performance were incorporated in the modeling system.

To varying degrees, the use of system dynamics to ascertain the recovery potential of the postattack economy incorporates many of the institutional features of the economic system that are not typically incorporated in economic models. That is, there are a number of implicit institutional assumptions that underlie the formulation of an economic model. These assumptions--whether made explicit or not--deal not only with the economic infrastructure of the economy, but the political and social infrastructure as well. It is assumed that there is a viable medium of exchange in existence to facilitate market transactions. It is also assumed that there is an established system of property rights and legal system under which economic activity occurs. It is assumed that the primary method used for the allocation of resources is the market mechanism--the interaction of market forces. It is assumed that a system of incentives as embodied in the tax system is well established. Moreover, it is assumed that incentives exist for the production of goods and services--a profit motive--and there are incentives for human

capital to be offered in labor markets. With respect to the latter point, a sociocultural system that has evolved over time is assumed to guide social behavior and to complement the functioning of the economic system.

Clearly, there is a large difference between the application of economic models to simulate the activity of the physical economic infrastructure--land, labor, capital, and material inputs--in an environment where all of the institutional features of the system are well-established and operative over a number of years and an application in an environment where political, economic, and social institutions are either destroyed or seriously impaired. Simulation of economic activity in the latter context must necessarily incorporate explicit representation of all of the political, social, and economic institutions--and their interrelationships--to obtain meaningful results. Or, alternatively, combining drastic changes in <u>both</u> the physical and institutional arrangements in the economy lead to a large number of possible outcomes that are quantitatively unpredictable.

The importance of this latter point has not gone totally unnoticed in the literature on postdisaster economic recovery. As discussed in Chapter 6, Dresch and Ellis (1966) undertook a detailed systems study of the interactions between the sociocultural, political, and economic subsystems of the national entity to isolate potential problems that may impinge on postattack recovery. On a qualitative basis, they identified inputs to and outputs from each of the subsystems that characterize the national entity. While they recognized that a quantitative model depicting the interrelationships between various components of the national entity would provide valuable insights into the operation of the postattack economy, data limitations proved prohibitive. On the use of a model to characterize the functioning of the national entity and prospects for recovery, Dresch and Ellis observed:

> Although systems analysis has been used (in this study) to arrange these inputs into a frame of reference, it seems clear that no model or simulation, however vast, could usefully encompass or faithfully distill the essence of the whole U.S. society. (Dresch and Ellis, 1966, p. 13).

The implications of Dresch and Ellis' assessment for modeling the postattack recovery potential of the U.S. economy where all strata of the national entity would be seriously impaired--if not totally destroyed--are quite clear.

Based on examining the various contributions to the literature on the physical infrastructure of the postattack economy, three conclusions can be drawn related to the potential for economic recovery. First, the magnitude of potential destruction of economic resources under the various hypothetical attack scenarios considered has been documented. Second, partially as a result of the first, problems that are of potential significance in harnessing the surviving resources of the postattack economy into a viable productive economy have been detailed. Third, the economic conditions--in a conceptual sense--under which re-

covery is likely to occur have been demonstrated. These conditions have been discussed by Winter (1963):

> In aggregative terms, the process of achieving viability can be viewed as a race between the reconstruction of the capital stock (and thus the recovery of output) and the depletion of the inventories from which essential needs are being met in the meantime. (Winter, 1963, p. vi).

In Winter's conceptual model used to illustrate conditions under which the economy will stagnate, collapse, or recover, surviving labor and capital were assumed homogeneous, with the ratio of the latter to the former determining the productivity of labor. Output of the economy is used to provide the subsistence needs of the labor force, a fixed commitment determined by the government--national defense and welfare for the incapacitated and impoverished, for example--and replenishment of the capital stock. Any level of output larger than these commitments was assumed to be invested to augment the surviving capital stock.

To demonstrate the recovery potential of the economy, Winter assumed that there is some hypothetical level of capital stock--given a level of surviving labor and a fixed government commitment--that is necessary to provide output that will satisfy subsistence requirements, the fixed commitment, and replenishment of the capital stock. Without an inventory of food, if the surviving capital stock is below the hypothetical level, the economy is nonviable. Moreover, without an inventory of food, the economy will stagnate (recover) if the surviving capital equals (exceeds) the hypothetical level needed to meet the subsistence requirements of labor, the fixed government commitment, and replenishment of the capital stock. On the other hand, given an initial stockpile of surviving food, the economy can recover with the surviving capital stock less than the hypothetical level if food stockpiles are sufficiently large to enable the combination of labor and capital to replenish the capital stock to at least the hypothetical level before food stockpiles are depleted. Hence, postattack recovery is a "race" between reconstruction of the capital stock and depletion of food inventories.

There has been no definitive quantitative statement on economic recovery to complement Winter's qualitative statement on the recovery potential of the U.S. economy. The quantitative assessments of economic recovery that have been presented in the literature are merely suggestive of recovery potential if the institutions that guide productive activity do not impede performance. In the best of circumstances where the simulation horizon is short and the viability of economic institutions is not questioned, economic science does not lend itself well to predictions. What is known, however, is that given an economic program that provides a productive environment for surviving economic resources, the surviving economy can be "directed" toward a recovery path.

A critical area that has virtually been ignored in research on the physical infrastructure in the aftermath of a generalized disaster is the potential role of the international economy in relieving bottlenecks. Typically, models developed to simulate recovery have either ex-

plicitly or implicitly assumed that the import sector is neutral; that is, it has no impact on recovery.*

Historically, foreign assistance has played an integral part in the recovery of nations from relatively large-scale, war-induced disasters. Foreign assistance can take many forms depending on the global extent of the disaster. Aid can originate from nations not directly affected by nuclear disaster. It can originate from multinational corporations that have productive assets in foreign countries. Or, conceivably it could be derived from stockpiles of critical intermediate and final goods that have either been placed in foreign nations or sufficiently protected from the effects of nuclear attack.

Unfortunately, very little research has been undertaken on the importance of the international sector in economic recovery from nuclear attack. In a recent paper, Jimmy Wheeler (1980) began his discussion of the international economy by stating:

> A major nuclear attack on the United States would seriously disrupt the world economy. Yet, studies and planning concerning recovery after a nuclear war have concentrated almost exclusively on conditions and resources within borders of the combatants. (Wheeler, 1980, p. 1).

Wheeler argued that the world economy has become much more interdependent and that supplies of materials or capacity necessary to produce supplies critical to recovery are presently much more dispersed. Wheeler's main concern was that effective planning for use of extra-U.S. sources of economic resources is virtually nonexistent. Depending on the magnitude of the attack--counterforce versus countervalue, for example--a whole range of opportunities for international assistance is available. What is needed is a coordinated plan that involves not only agencies of the Federal government but diplomatic coordination as well.

Another important international issue in the aftermath of a large-scale nuclear war is the structure of the world economy--supply sources and the composition of demand. Writing more than two decades ago, Massell and Wolf (1962) addressed that issue. In the study, the authors attempted to determine if the priorities for development of specific industrial sectors in recovering from nuclear attack are similar to the priorities for development in underdeveloped countries. While the results of the study were not conclusive, the authors conjectured about the international demands for resources in the aftermath of a large-scale nuclear conflict:

> This means that there would be conflicting economic interests between the recuperating states and the undamaged states. The former would experience a vast increase in demand, together with a sharp decline of capacity in high-priority recuperation industries; while the underdeveloped areas would have, and

---

*The exceptions to this statement are provided in Chapter 3 where individual modeling studies are reviewed.

would undoubtedly continue to have, a large demand for essentially the same types of capacity, as suggested by our analysis. The resulting situation would be likely to result both in a serious interruption in the development of the underdeveloped countries and, at the same time, a severe difficulty on the part of the industrial states in recouping their capacity. (Massell and Wolf, 1962, pp. 24-25).

7.4. INSTITUTIONAL INFRASTRUCTURE

Published research on institutional issues in the aftermath of a generalized disaster has been, almost without exception, speculative or superficial, generally lacking an analytical basis. Indeed, one of the primary recommendations advanced by many contributors to the literature on the postattack economy is the need for more rigorous analysis of economic institutional issues.

What is needed in the area of economic institutional planning is further study on integrating all of the organizational, monetary, and fiscal tools that are at the disposal of all levels of the government into a consistent recovery program. The program is required to ensure that physical resources are used most efficiently in recovery--especially in the early aftermath of the disaster. Besides resolving problems with entangling legal arrangements, a coordinated program must be devised to resolve all of the organizational, monetary, and fiscal problems resulting from the disaster.

To illustrate the importance of coordination, it is clear that, from the standpoint of equity, a system of damage compensation must be developed as part of fiscal reform or, alternatively, an extra-tax program of damage compensation must be developed that is consistent with the fiscal program. The program of damage compensation must be coordinated with the approach that will be used for federal revenue generation. This is no less true for a currency reform which must be coordinated with overall monetary policy in the postattack period.

The importance of economic policy has been underscored in the economic reconstruction efforts of countries following World War II.* For example, what is apparent from the economic stagnation experienced by Germany following World War II is that economic management and policy were improperly devised. The result was a degree of economic stagnation that could have been ameliorated with the implementation of an economic reconstruction program that relied less on direct controls and central administration and more on the market mechanism.

---

*Although there are no perfect historical analogues for the economic problems that a nation will potentially confront in the aftermath of both large-scale destruction of human and physical resources and impairment of economic institutions, the experiences of countries that underwent reconstruction after World War II are at least suggestive of some of the economic problems that an attacked nation will both confront and be required to solve.

In Germany, a policy of repressed inflation in conjunction with a host of commodity controls that superceded the market mechanism led to economic stagnation and reversion to an exchange system that only partially involved the use of the prevailing currency. The economic reforms initiated in June of 1948 that revalued the currency, lifted direct controls, and changed the tax system led to a dramatic reversal of economic output and productivity.*

Stagnation of the German economy was attributable to three interrelated factors. First, the occupying powers continued a very rigid system of wage and price controls that was carried over from the German wartime economy. Second, earned income was taxed heavily. Third, the authorities failed to eliminate the enormous amount of excess purchasing power that was present in the economy.

Perhaps the most important manifestation of these economic policies was their effect on incentives to both produce and work. With respect to production incentives, a rigidly controlled system of absolute and relative prices in conjunction with other factors that characterized the German postwar economy--declining labor productivity and shortages of raw materials, for example--did not allow adequate compensation for production. Thus, there was no incentive to produce at prevailing price levels. The lack of production incentives led to shortages of consumer goods. The lack of consumer goods in concert with the excess liquidity in the economy provided no incentives for the work force to offer their services in labor markets. Money compensation, in general, was not sufficient to attract labor in an economy where consumer goods were not available and there was already an excess amount of purchasing power.

Many of the contributors to the literature on postattack recovery have expressed concern that the same types of control measures used both in German reconstruction and in the United States during World War II dominate planning for recovery from nuclear attack. In World War II, the Federal government needed to allocate more resources to the production of defense-related goods at the expense of consumer goods. To accomplish this redirection of economic resources, an elaborate system of price controls, material plans, incentive programs, and allocation schemes was devised to supplement the free-market economy.

A problem that arises in using the World War II experience as an economic planning blueprint for recovery in the aftermath of a nuclear

---

*As discussed in the previous chapter, a caveat must be added when attributing Germany's dramatic economic turnaround wholly to reforms initiated in June of 1948. Many authors have pointed out that other factors may have contributed to the economic stagnation in the immediate postwar period. Hirshleifer (1963), for example, pointed out that, besides the policy of repressed inflation, there were two other organizational forces at work in Germany in the immediate aftermath of the war--restrictive economic policies of the Allies and social and political disorganization. Hirshleifer concluded, however, that these two forces were secondary to the policy of repressed inflation in explaining Germany's stagnation.

attack is that the institutional infrastructure under which the World War II plan was implemented was established and functioning over a number of years. That is, there existed a well-defined system of property rights, incentive systems, a monetary system, a legal system, and the like. In the context of a generalized disaster resulting from a nuclear attack, the viability of this infrastructure will be seriously impaired, if not nearly destroyed.

Therefore, the problem confronting emergency planning extends well beyond development of an elaborate system of controls and allocation schemes to be used in directing the economic recovery effort. The problem encompasses re-creating substantial portions of the institutional environment. An important problem in the postattack environment is the management of economic resources, which includes any form of government intervention in the economy. Is nationalization of all economic resources administered by a central authority the optimal approach? Or should economic recovery rely on a market-oriented economy?

There is a tendency on the part of many to allocate total responsibility for postattack recovery to the Federal government. Short of total nationalization of all economic resources, it is very easy to conclude that, in a postattack economy, the Federal government should: (a) impose and enforce wage and price controls; (b) provide realistic market signals for investment and exchange purposes; (c) ration consumer commodities; (d) allocate materials to their most essential uses in production; (e) determine investment choices with the highest marginal return; (f) ensure that the prevailing currency is used in exchange; (g) provide all of the necessary support services for production; and (h) perhaps most importantly, enforce all of its directives.

However, what is readily evident from a study of various disaster scenarios is that the federal government cannot assume the role of the "invisible hand" in economic recovery. That is, the allocation of economic resources that, for the most part, is made by innumerable decentralized decisions in the preattack economy cannot be superceded by a system in which the central authority makes all of these decisions. There are at least two important reasons for this assertion.

First, resources needed for effective central management of the economy will more than likely not be available. The lack of management resources is attributable to both the likely destruction of centers of government and the magnitude of managerial resources required for making resource allocation decisions in an economy as complex and as potentially imbalanced as the postattack U.S. economy. Centralized control of economic decisions would also necessitate an enforcement cadre that extends well beyond the bounds of likely surviving enforcement resources.

Second, the size of the resource management base notwithstanding, the Federal government does not have the experience or the expertise to assume all of the decentralized decisionmaking that characterizes the preattack economy. For example, it is anticipated that one of the most important stimulants to recovery--at least in the early postattack recovery phase at the local level--will be reliance on nonconventional or expedient production processes that will circumvent the need for some

types of productive inputs that were used preattack. The localized nature of these activities is conducive to on site--and not governmental--implementation. Therefore, even if all of the managerial resources of the Federal government managed to survive a large-scale disaster--because of, for example, extensive preattack planning to ensure survival--and other institutional arrangements were reestablished to provide the proper economic incentives--a functioning currency, for example--the capability of a central authority to control a damaged economy is limited.

Several contributors to the literature on postattack economic recovery have argued that nationalization of all economic resources and centralized control of economic activity for at least a short period of time may be desirable because, if effectively administered, it would eliminate many of the other institutional problems in the postattack economy. If the allocation of all materials for production and consumer goods were accomplished through central administration, then, for example, the requirement for currency reform would be less demanding because markets would not exist and currency would not be required to facilitate exchange. Economic activity would proceed on the basis of government proclamation. The two aforementioned arguments on the level of surviving managerial resources and expertise to control the economy are applicable here. Reliance on a policy of nationalization and control for a limited time in the immediate postattack period is even less appealling if one assumes that the most critical period in the recovery effort is in the early stages of reorganization when emphasis should be placed on rebuilding the capital stock.

If central control of economic resources is eliminated from consideration as nonworkable or inefficient, presumably some form of a market mechanism will guide economic activity without reliance on the government to allocate resources. Under this assumption, the role of the Federal government in economic stabilization must be delineated. That role, of course, is a direct function of economic problems that are likely to arise in the postattack environment. One of the most important problems is the likely change in realistic relative prices from their preattack relationships. Some authors have argued that wage and price controls are the solution to the anticipated problem of wild price fluctuations. Assuming that an effective currency reform can be implemented, it is questionable whether wage and price controls are advisable in a postattack economy.

There are several compelling reasons for this assertion. To be effective and prevent reversion to barter, a system of wage and price controls must match legal price ceilings with realistic prices determined by the relative availability of surviving resources. In peacetime use, price ceilings for controlled goods are established and then periodically adjusted to reflect cost increases. In wartime--the U.S. economy during World War II, for example--price controls were imposed because a large amount of economic resources were directed into the production of war-related goods at the expense of the production of consumer goods. Consumer goods were rationed because of their relative scarcity and, to prevent rapid increases in the level of prices, price ceilings were imposed on a number of consumer goods. A price control administration was

created to ensure that legal prices were consistent with current market conditions.

These applications of price controls in an undamaged economy can be differentiated from what is expected in a postattack economy because of the lack of information on realistic relative prices. That is, a large-scale and disproportionate destruction of resources would cause a drastic alteration in realistic relative prices from what prevailed in the preattack economy. Any attempt to freeze prices at preattack levels for any period of time would result in a serious distortion of relative prices. Moreover, because of a lack of finely detailed information on the destruction of resources, substitution possibilities, and the pace of recovery in individual sectors of the economy, it is improbable that the Federal government could determine a legal set of prices consistent with realistic prices based on prevailing conditions in the economy.

The economic consequences of a failure to match legal and realistic prices is well documented. In Germany following World War II, for example, the occupying powers continued a system of price controls established by the Nazi regime. Relative prices in the aftermath of the war were nearly the same as those set a decade earlier in 1936. This distortion in relative prices led to shortages of important commodities because of disincentives to produce at legal prices that only partially covered the costs of production. In 1946, for example, it has been estimated that between 30 and 40 percent of industry in Germany could not recover costs of production because of the imposition of price controls.

Given the nonviability of wage and price controls, what is needed is a study to explore various options for providing price signals in a disproportionately damaged economy. More than two decades ago, Winter offered some unconventional suggestions for dealing with this problem [National Academy of Sciences (1963)]. For the most part, these suggestions were conceptual alternatives to a system of wage and price controls. The solutions suggested by Winter were (a) advisory prices developed by the government and based on some form of damage assessment; (b) a futures market for essential commodities; or (c) a system of select price guarantees. All of the suggestions were intended to provide realistic price signals in a market economy to guide investment behavior.

Winter's advisory price alternative is an example of an area in which the Federal government can play an important role in the postattack economy--namely, providing information. Under the advisory price proposal, the government would estimate realistic relative prices and convey that information to the private sector to both guide exchange and promote efficient investment decisions. The advisory prices would be estimated on the basis of some type of damage assessment system that would determine the relative scarcity of resources in the economy and, therefore, provide the basis for estimating relative prices. Damage as-

sessment systems currently in existence could easily serve that purpose.*

Winter's two other suggestions of futures markets and select price guarantees are also intended to provide price signals to guide investment behavior. Futures markets in a peacetime economy are used primarily to guide investment decisions in markets where the price is subject to large fluctuations. In the postattack economy, the intent would be to establish futures markets for commodities that are essential in the recovery process. In this way, producers would be provided price signals to guide investment decisions. A system of select price guarantees is intended to accomplish the same end. If the Federal government guaranteed the future price of some essential commodities, it would enhance prospects for funneling investment expenditures for the production of those commodities.

Thus far, it has been argued that the most effective role of the Federal government in resource management would be to provide the foundation for what is, in essence, a market-based economy. Recovery would be based on the incentives provided to the private sector. Winter's unconventional proposals for establishing a contrived market mechanism are suggestive of the approaches that one could take in guiding market activity under the assumption that the Federal government's role in economic recovery is supportive rather than controlling. Other proposals, excluding wage and price controls, may have as much merit.

The role of the Federal government in economic recovery outside of developing a market mechanism is also important. Many authors have argued that a system of commodity controls must be established to ensure that important inputs are directed to their most essential uses. Again, the problem of information available at the smallest level of detail--the individual plant level, for example--is a constraining factor. The fundamental question is whether the Federal government has the required information available to make efficient resource allocation decisions. The level of information required is at the individual input level and requires knowledge of, among other things, inventories, substitution possibilities, and investment expenditures.

Several authors have advocated development of an information system which would provide the Federal government the information necessary to control the economy. Dresch (1964), for example, suggested an elaborate master scheduling system which would be the basis for making investment decisions and directing material flows in the postattack economy. The scheduling system would require that the Federal government decide priorities for production and would have 509 regional institutions provide information for the master plan. However, upon further reflection, Dresch (1968b) abandoned the idea of a master scheduling system because

---

*It must be emphasized that use an economic damage assessment system to provide crude estimates of relative scarcities and, hence, relative prices is not the same as simulating economic recovery or using an economic model to micromanage the activities of all economic agents.

of its unwieldiness in the early postattack recovery period where it will be essential for timely investment decisions.

The area in which the Federal government's direct participation in the recovery effort would have the most marked impact is in ensuring that important support services and infrastructure are developed to accommodate the recovery effort. The most prominent supporting industry is transportation. The Federal government presumably would have a monopoly of information on the physical destruction of the transportation infrastructure--roads, bridges, rail lines, air facilities--and the physical destruction of economic resources and could, therefore, play an important role in reestablishing physical links between geographical areas.

Indeed, transportation planning becomes more urgent if one assumes that surviving physical resources will be dispersed in "pockets" or "islands" that are unaffected by the direct effects of an attack. The importance of transportation for economic recovery under this scenario is obvious. If a transport network can be devised to overcome the problems of regional or "island" interdependence and resources in the aggregate survive in sufficient quantities to ensure that capital reconstruction can be accomplished, the likelihood of economic recovery is that much more improved.*

With respect to monetary reform, nearly all commentators have emphasized the need for planning to prevent a postattack barter economy. The importance of a currency reform to adjust the level of liquidity in the wake of a disaster has historical precedent. In Germany, for example, the authorities pursued a policy of repressed inflation in which excess purchasing power in the economy did not did not lead to rapid increases in the price level because wage and price controls were imposed. Had the authorities abandoned the system of price controls without monetary reform, the economy would have experienced a period of rapidly increasing prices. The currency reform of June 1948 adjusted the liquidity in the economy to match the available supply of goods and, therefore, attained a balance between the monetary and real economy.**

---

*With respect to geographically isolated "islands of survival," it is not inconceivable that many independent regional economies will arise in the aftermath of nuclear attack. The regions may create their own currency, develop their own management resource system, and, in all other economic respects, function as a separate economy. Some commentators on postattack recovery have encouraged the creation of multiple currencies in geographically isolated areas as a means of avoiding a barter economy.

**It must be emphasized that the excess liquidity in the German economy during the Allied occupation in the aftermath of the war was the manifestation of years of economic controls imposed by the Nazi regime. In the postattack recovery context, the possibility of a liquidity problem is based on the potential disproportionate destruction of real goods and purchasing power. However, the economic implications in both cases are similar.

To resolve potential monetary problems in the postattack economy, a number of authors have advocated a currency reform--the so-called "blue money" proposal--in which a new scrip would be issued to replace the preattack currency at an exchange rate sufficient to eliminate excess liquidity and, hence, the possibility of rapid inflation. Other authors have discussed the need for backing the new currency with either gold or appropriated food supplies or petroleum to ensure its functioning as a medium of exchange. Others have argued that multiple currencies should be established--at the state or Federal reserve district level, for example--because of a potential lack of confidence in a national currency.

What is evident is that a policy of stockpiling the preattack currency to be used in the postattack economy is not consistent with solution of one of the most important problems confronting the economic recovery effort--the control of financial liquidity in the face of the disproportionate destruction of resources. A more effective approach may be to stockpile a new scrip--the so-called "blue currency"--to be used as part of a currency reform early in the postattack economy.

An important issue in a postattack environment that does not have a close historical analogue is the attack's effect on the international monetary system. Unfortunately, there has been little research undertaken on the implications of nuclear war for the international monetary system and, more specifically, on the impact of the demise of the dollar on the international monetary system. Quester (1979), for example, virtually dismissed the significance of the effect of the dollar's demise on the international economy. In identifying trends that tend to ameliorate problems with recovery, he wrote:

> The basic monetary policy of the U.S. has in the past decade become less burdened with the role of serving as a world reserve currency. As a net result, it will be easier for the U.S. to adjust quickly to the monetary policies required entirely for the domestic recovery process, as the world reserve role would unlikely be filled by the dollar in the post-attack environment. (Quester, 1979, p. 5).

Quester's argument that the U.S. dollar would not play a significant role in the postattack world economy does not address the problem of dollar-denominated international assets in the aftermath of war.

Writing a year later, Wheeler (1980) outlined some of the problems that may arise in international currency markets in the event of nuclear war. Preattack problems are expected to arise in the event that international tensions increase. With a perceived risk of war, holders of the U.S. dollar will tend to exchange dollars for other strong currencies, thereby driving the value of the dollar to low levels. The problem is exacerbated because other strong international currencies are issued by countries which are potential combatants in the war. Wheeler believed that planning for nuclear conflict should include the potential effect on the international monetary system:

> Indeed, pre-attack planning for a possible nuclear exchange must include consideration of actions to ameliorate possible pre-attack monetary chaos which could seriously interfere with post-attack economic recovery, or for that matter with the re-establishment of peacetime economic relations in the event the crisis did not escalate into a nuclear war. (Wheeler, 1980, p. 6).

The severity of an international financial crisis in the postattack period clearly depends on the magnitude of the hostilities. In the event of a counterforce strike where a large fraction of economic capacity survives and prospects for recovery are relatively favorable, the negative impact on the dollar should be short-lived, with longer run prospects more favorable. On the other hand, if the destruction of economic resources is relatively large--in, for example, a combined counterforce/countervalue strike--the international impact would be far more serious. Wheeler wrote:

> If an attack destroyed a major fraction of productive capacity in the United States, the value of the dollar would fall dramatically, creating serious international financial chaos, over and above the problems created by termination of most trade flows to and from the United States, and the disruption caused by pre-attack speculation. (Wheeler, 1980, p. 7).

In the postattack economy, the tax system is crucial in at least two areas. First, it has an obvious importance in directing expenditures from current consumption to savings. The savings, of course, would be utilized to finance investment in plant and equipment that will be used to increase future levels of consumption. The second area where taxes play a prominent rol` is the postattack incentive system. In Germany during reconstruction, for example, high levels of taxation in conjunction with excess liquidity in the economy proved to be a disincentive for working.

Perhaps no aspect of postattack economic recovery has elicited more divergent views than those associated with the tax system. Suggestions have varied from using the tax system as a means to redistribute surviving wealth--a damage compensation system--to using it as a vehicle for absorbing excess purchasing power. Although a number of tax types have been offered for consideration--national sales tax, value-added tax, progressive income taxes, estate taxes, capital gains taxes, taxes on wealth--a comprehensive program of taxation consistent with other economic tools has not been offered in the literature. One of the fundamental disagreements has been over the use of steeply progressive income taxes. On the one hand, it has been argued that progressive taxes offer a viable means to redistribute wealth. On the other hand, it has been argued that progressive taxes would stifle economic growth and, thus, the redistribution of wealth problem should be addressed outside of the tax system.

Authors contributing to the literature on a postattack system of taxes have in general pointed out the need to use the system for directing resources into investment and away from consumption goods. Dresch,

for example, argued that a tax system, if devised properly, could contribute to eliminating excess purchasing power and divert income away from current consumption to savings. His proposal of forced savings would attach a tax surcharge on every taxpayer beyond the level of normal withholding for Federal revenue generation. The additional tax withholding would reduce current purchasing power and would be used for investment purposes. The tax surcharge would be used to purchase investment certificates by individual taxpayers that could be converted into various public and private securities to help finance recovery. The program would be eliminated after the economy achieved a long-run recovery path.

In the aftermath of a large-scale disaster, the system of incentives for both labor and producers will be dramatically altered. The majority of research on postattack recovery has focused on harnessing surviving physical resources. Typically, it has been assumed that labor will perfectly complement surviving physical resources to provide the foundation for recovery.

These types of analyses do not account for the behavior of the stock of human capital in the aftermath of a nuclear attack. Clearly, an incentive system must be reestablished to induce the surviving stock of human capital to offer their services in labor markets. Some contributors to the literature have dismissed planning in this area as futile because of the likelihood of mass panic. In a study of the social impacts of disasters in general and the social impacts of bombing in particular, Ikle (1958) summarized this view:

> It has occasionally been postulated that large-scale destruction would lead to mass panic, and the attention given to the problem of panic has frequently overshadowed consideration of all other possible social effects from bombing. (Ikle, 1958, p. 14).

However, in his analysis of historical bombing disasters--primarily in World War II--Ikle found no evidence of this phenomenon:

> Reports from very large disasters of the past fail to show any significant mass panic among the afflicted population. Findings from Hiroshima, Nagasaki, Hamburg, and other areas of large bombings in World War II do not indicate that serious mass panic occurred at any time. (Ikle, 1958, p. 15).

The absence of mass panic does not eliminate the problem of postattack incentives. In a study based on the views of a panel of "experts" on the psychological aspects of nuclear disaster, Bruce Alnutt (1971) of Human Sciences Research, Inc. attempted to ascertain the effect of nuclear war on economic recovery. With respect to survival and labor force participation, the study concluded:

> . . . after six months, the panel predicts that over two-thirds of the potential labor force would be available without constraints and without degraded efficiency. At earlier periods, however, the picture is not so bright. As late as a

> month after the attack, the panelists expect that <u>less than half</u> of the potential labor force would be willing to work without immediately beneficial (i.e., non-monetary) compensation and that, of these, one out of five would be able to function only at a level "greatly degraded" from his normal--in other words, <u>only about a third would be expected to perform as they would have under preattack conditions</u>. (Alnutt, 1971, p. 100).

This conclusion is ominous when one considers the importance of the early months of postattack recovery. Based on this and other considerations, the authors called for increased attention on the psychological aspects of economic recovery:

> The complete lack of agreement regarding the postattack value of money and the emergence of a barter system, and the polarization regarding the possibility of national postattack economic planning is of the most profound consequence. No area... is more in need of deeper investigation. (Alnutt, 1971, pp. 124-125).

Increased attention must be devoted to ensuring that a postattack incentive structure is established and maintained throughout the recovery period. Ideally, incentives both to produce and work should be a large consideration in developing a comprehensive program of institutional reform in the aftermath of a generalized disaster.

8. CONCLUSION

The purpose of this report has been to analyze, synthesize, and assess the extant literature on postdisaster economic recovery in the context of providing a background for policy development. The six preceding chapters have provided both summaries of research undertaken on the physical and institutional infrastructures of a postdisaster economy and an assessment of that research. As those chapters have pointed out in various degrees of detail, the analysis of economic problems likely to emerge in the aftermath of disasters has proceeded along four fronts: (1) economic resource assessments; (2) viability studies using formal economic models; (3) individual industry studies; and (4) economic resource management assessments, including questions related to the institutional infrastructure of a postdisaster economy.

Four conclusions were drawn from the assessment of the literature on postattack economic recovery. First, the magnitude of the potential destruction of economic resources under various hypothetical attack scenarios has been documented. Second, problems that are of potential significance in harnessing the surviving resources of the postattack economy into a viable productive economy have been detailed. Third, the economic conditions--in a conceptual sense--under which recovery is likely to occur have been provided. Finally, the potential for long-term recovery is contingent on the optimal use of economic control devices at the disposal of the government.

Since the discussion was focused exclusively on economic issues, a number of other factors that may impinge on postdisaster recovery were not considered. One of the most important factors is ensuring the long-term maintenance of the surviving population.* Also, it was assumed that the United States will survive as a sovereign nation and, under the continuity of government program, political leadership will be maintained. Finally, it was assumed that long term environmental effects of the disaster--biological and climatological effects, for example--will not prove to be significant obstacles to recovery.

Based on the assessment, four areas were identified which, if addressed, could significantly improve planning for economic recovery in the aftermath of a disaster. First, attention must be devoted to isolating problems and developing control measures in the event of a prolonged nuclear conflict. Second, research should be undertaken to develop an economic management and stabilization program that is consistent with approaches to fiscal and monetary reform and damage compensation in a severely damaged economy. Third, as an extension of research undertaken over the past two decades, several key industries should be the subject of more intense scrutiny. The most prominent of these are the transportation and process control industries. Fourth, increased emphasis must be placed on problems and opportunities associated with

*In conjunction with this work, other studies are being conducted on population maintenance issues such as emergency food and water, national security food requirements, and emergency shelter.

the international economy in the aftermath of a large-scale nuclear disaster.

A scenario of prolonged nuclear conflict and attendant economic problems cuts across all facets of planning for economic recovery--economic stabilization, individual industry performance, and international repercussions. However, very little research has appeared in the literature which addresses potential problems in an economy increasingly fragmented over a period of months. This research could be incorporated as one component of the three other studies on generalized disasters to be discussed below.

As the discussion in Chapter 7 emphasized, the most important aspect of postattack economic recovery planning is developing a consistent program for recovery, encompassing all of the economic tools at the disposal of the government to ensure the proper environment for productive economic activity. The discussion in prior chapters discussed (a) the managerial, fiscal, and monetary problems that are likely to arise in a postattack economy; (b) the problems encountered with economic control devices used in Germany in the aftermath of World War II; and (c) possible solutions to the problems along with limits of feasible government intervention. What is needed here is a research effort that provides a detailed array of approaches to solving stabilization, monetary, fiscal, and damage compensation problems, along with their strengths and weaknesses. The research should develop a consistent approach to economic reform across all reform measures. It should not be limited exclusively to Federal reform but should encompass subnational jurisdictions as well.

Studies of individual industries that were the subject of the discussion in Chapter 5 have isolated many problems that may arise in key industries as a result of a disaster. The studies provide a sound basis for planning and developing corrective programs for recovery. However, among the many industries that are critical to recovery, there are two which warrant further study--transportation and process control. A series of studies at the Stanford Research Institute in the 1960s addressed the vulnerability and viability of all of the transport modes in the aftermath of hypothesized nuclear attacks. Because of changes in both the transport resource base and the strategic threat over the past two decades, however, the studies are somewhat outdated. In the "islands" or "pockets" of survival context, transportation is viewed as one of the most important service industries. With respect to process control, Van Horn and Crain's (1975) study of the industry from both a supply and demand standpoint underscored the potential severity of problems that could arise as a result of a generalized nuclear disaster. From a supply standpoint, geographical concentration of important inputs poses significant problems for recovery. From the standpoint of demand, rapid improvements in the technology used for industrial process control increasingly contributes to the vulnerability of industrial control processes and, hence, industrial output.

Perhaps no area in the context of postattack recovery has been more overlooked than the effects of a generalized disaster on the international economy. Many studies have alluded to the potential importance

of foreign sources of supply to ameliorate bottlenecks, for example, but no study has focused specifically on supply sources and problems that may be encountered in obtaining vital imports. These problems include international transport and the possibility of a reluctance to trade on the part of foreign governments. Moreover, a question of critical importance is the effect of a nuclear conflict on the U.S. dollar specifically and the international monetary system generally. Detailed analysis of these potential international problems is a necessity in the context of planning for domestic economic recovery.

BIBLIOGRAPHY

Adams, Larry W. et al., 1969, Water and Sanitation Systems Postattack Study, 2 Volumes, Engineering-Science, Inc., Acadia, California, ES-704, August.

Adelman, Frank L. et al., 1976, Intermediate and Long Term Effects of Limited Nuclear Attacks, System Planning Corporation, SPC-277, September.

Addington, Lloyd B., 1968, "Postattack Viability of United States--1975", In National Academy of Sciences, 1968, Proceedings of the Symposium on Postattack Recovery from Nuclear War, Held at Fort Monroe, Virginia, November 6-9, 1967, Washington, D.C., April.

Allen, Stephen G., 1968, A Postattack Economic Model, Stanford Research Institute, Menlo Park, California, Project 5188-328, August.

Allen, Stephen G., 1969, A Postattack Economic Model Study, Stanford Research Institute, Menlo Park, California, October.

Alnutt, Bruce C., 1971, A Study of Consensus on Psychological Factors Related to Recovery From Nuclear Attack, Human Sciences Research, Inc., McLean, Virginia, HSR-RR-71/3-Di, May.

Anderson, Dan, 1974, "The National Flood Insurance Program: Problems and Potential", Journal of Risk and Insurance, December.

Anderson, Dan R. and Maurice Weinrobe, 1980, Effects of a Natural Disaster on Local Mortgage Markets: The Pearl River Flood in Jackson, Mississippi, April 1979, Institute of Behavioral Sciences, University of Colorado, Denver, Colorado, Working Paper #39,.

Anderson, William A., 1969, Disaster and Organizational Change: A Study of the Long-Term Consequences in Anchorage of the 1964 Alaska Earthquake The Disaster Research Center, Columbus, Ohio.

Andrews, Benjamin V. and Harvey L. Dixon, 1964, Vulnerability to Nuclear Attack of the Water Transportation Systems of the Contiguous United States, Stanford Research Institute, Menlo Park, California, SRI Project IMU-4536-421, May.

Ayres, Robert U., 1966a, On Inductive Inference about the Postattack World, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, HI-647-RR, January 28.

Ayres, Robert U., 1966b, Models of the Postattack Economy, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, HI-468-RR, August 1.

Ayres, Robert U., 1966c, Methodology for Postattack Research, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, HI-647-RR, August 1.

Ayres, Robert U., 1966d, On Damage Assessment Models, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, HI-693-RR, December 30.

Baca, John J., Peter B. Bjorklund, and Richard K. Laurino, 1975, Natural Disaster Scenario Generator, Center for Planning and Research, Inc., Palo Alto, California, November.

Baer, Stephen, 1968, Preliminary Estimates of Labor Demands in the Post-attack Economy, Institute for Defense Analyses, Arlington, Virginia, Internal Note N-585(R), October.

Baker, Lawrence C., 1973, "Availability and Desirability of Earthquake Insurance," In Earthquakes and Insurance, Center for Research on the Prevention of Natural Disasters, California Institute of Technology, Pasadena, California.

Ballard, Kenneth P., 1983, The Structure of a Large-Scale Small-Area Multiregion Model of California: Modelling an Integrated System of Urban, Suburban and Rural Growth," Regional Studies, October.

Barton, Allen, 1969, Communities in Disaster: A Sociological Analysis of Collective Stress Situations, Doubleday and Co.

Baum, S. and Francis W. Dresch, 1971, Analysis of Damage Level Measurement Criteria in Terms of Potential for Economic Recovery, Stanford Research Institute, Menlo Park, California, SSC-IN-71-79, September.

Baumann, Duane D. and John H. Sims, 1978, "Flood Insurance: Some Determinants of Adoption," Economic Geography, July.

Bear, Donald V. and Paul G. Clark, 1959, Which Industries Would Be Most Important in a Postwar U.S. Economy?, The Rand Corporation, Santa Monica, California, RM-2443, September.

Bear, Donald V. and Paul G. Clark, 1960, The Importance of Individual Industries for Defense Planning, Rand Corporation, Santa Monica, California, P-2093, September 15. (A version of this paper also appears in the American Economic Review, May 1961.)

Bell, M.C. and C. V. Cole, 1967, Vulnerability of Food and Livestock Production to Fallout Radiation, Agricultural Research Laboratory, Oak Ridge, Tennessee, September.

Belzer, D.B. and J.M. Roop, 1984, Economic Recovery Dynamics Model, Volume I: Modifications and Simulations; Volume II: User's Manual; Volume III: Model Documentation, Battelle Pacific Northwest Laboratories, Richland, Washington, May.

Bensen, David W. and Arnold H. Sparrow, Editors, 1971, Survival of Food Crops and Livestock in the Event of Nuclear War, U.S. Atomic Energy Commission, #24 of AEC Symposium Series, CONF-700909, Washington, D.C., December.

Berger, Howard M., 1978, A Critical Review of Studies of Survival and Recovery after a Large-Scale Nuclear Attack, R&D Associates, Marina del Rey, California, RDA-TR-107006-009, December.

Berry, Paul, 1966, Some Problems in Relating Social Science Research to Policy Planning for Postattack Recovery, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, HI-692-D/2, June 13.

Bickley, Leonard J., 1967, Industrial Hardening Classification: The Spectrum of Characteristics of the Manufacturing Industry and Derivation of Industrial Family Groupings, Institute for Defense Analyses, Arlington, Virginia, Study S-263, July.

Bickley, Leonard J., 1968, Concentration of Population and Selected Essential Resources, Institute for Defense Analyses, Arlington, Virginia, Study S-300, Supplement, April.

Bickley, Leonard J., 1969, Geographic Concentrations of the Manufacturing Industries, Institute for Defense Analyses, Arlington, Virginia, Research Paper P-594, September.

Bickley, Leonard J. and Abner Sachs, 1966, Industrial Hardening Classification: A Methodology for Simplifying the Evaluation of Hardening Costs, Volume I: Text and Appendix A, Volume II: Appendix B, Institute for Defense Analyses, Arlington, Virginia, Study S-263, October.

Bickley, Leonard J., Jane-Ring Crane, and Edward S. Pearsall, 1968, "Estimates of Potential of U.S. Economy Following a Nuclear Attack in 1975," In National Academy of Sciences, 1968, Proceedings of the Symposium on Postattack Recovery from Nuclear War, Held at Fort Monroe, Virginia, November 6-9, 1967, Washington, D.C., April.

Bigelow, Charles D. and Harvey L. Dixon, 1963, The Effects of Nuclear Attack on Motor Truck Transportation in the Continental United States, Stanford Research Institute, Menlo Park, California, SRI Project 3711-400, January.

Billheimer, John W., 1967, Postattack Food Availability and Accessibility--A Case Study, Stanford Research Institute, Menlo Park, California, April.

Billheimer, John W., 1968, Postattack Food Availability and Accessibility: Albuquerque, New Mexico, Stanford Research Institute, Menlo Park, California, SRI Project MU-5576, November.

Billheimer, John W. and Harvey L. Dixon, 1964, Analysis of Postattack Food Processing and Distribution, Stanford Research Institute, Menlo Park, California, June.

Billheimer, John W. and Richard W. Hall, 1973, Local Utilization of National Food Resources, Stanford Research Institute, Menlo Park, California, SRI-1498, November.

Billheimer, John W. and Juliet McNally, 1982, Guidelines and Data to Support Plans For Reallocating Food During Crisis Relocation, Systan, Inc., Los Altos, California, D-180, December.

Billheimer, John W. and A.W. Simpson, 1978, The Effects of Attack on Food Distribution to the Relocated Population, 3 Volumes, Systan, Inc., Los Altos, California, September.

Billheimer, John W. and Lacy G. Thomas, 1970, Postattack Food Availability and Accessibility: Detroit, Michigan, Stanford Research Institute, Menlo Park, California, November.

Billheimer, John W. et al., 1975, Food System Support for the Relocation Strategy, Part I: Analysis and Case Study, Part II: Prototype Plans, Part III: Planning Guidelines, Systan, Inc., Los Altos, California, September.

Billheimer, John W. et al., 1978, Postattack Impacts of the Crisis Relocation Strategy on Transportation Systems, Volume I: Analysis and Case Study; Volume II: Revised Planning Guidelines; Volume III: The Role of Truckstops in Crisis Relocation, Systan, Inc., Los Altos, California, D-151, September.

Black, Robert H., 1970, The Effects of Hurricane Camille on Industry, Public Utilities, and Public Works Operations, URS Research Co., San Mateo, California, URS 792-2, March.

Black, Robert H. and William H. Van Horn, 1970, Development of Procedures for Assessment of Local Industrial Productive Capacity Following Nuclear Attack, URS Research Co., San Mateo, California, February.

Block, Ellery B. et al., 1977, Initial National Survivability Study: Summary Volume, Stanford Research Institute, Menlo Park, California, Technical Note SRD-EG34, October.

Block, Ellery B. et al., 1979, Critical Industry Repair and Reclamation Study: U.S. Rubber Industry, Science Applications, Inc., Huntsville, Alabama, SAI-80-788-HU, November 30.

Boesman, William C., J. William Grigsby and Robert P. Manly, 1970, Vulnerability of the Petroleum Distribution System: Detroit, Michigan, Checchi and Company, Washington, D.C., July.

Boesman, William C., Robert P. Manly and Richard A. Ellis, 1972, Total Resource System Vulnerability: Development and Application of a General Model, Checchi and Co., Washington, D.C., September.

Bowden, M.J., 1970, "Reconstruction Following Catastrophe: The Laissez-Faire Rebuilding of Downtown San Francisco after the Earthquake and Fire of 1906," Proceedings of the Association of American Geographers.

Brannen, Ted R., 1954, Economic Aspects of the Waco, Texas Disaster of May 11, 1953, Department of Sociology, University of Texas, Austin, Texas, Research Report No. 2, January.

Brite, Robert L. and Harris S. Segal, 1976, Zonal Transportation System Vulnerability, University of New Orleans, Division of Business and Economic Research, New Orleans, Louisiana, April.

Brookshire, D.S. and W.D. Schulze, 1980, Methods Development for Valuing Hazards Information, Institute of Policy Research, University of Wyoming, Laramie, Wyoming.

Brown, Stephen L., 1966a, Industrial Recovery Techniques, Stanford Research Institute, Menlo Park, California, SRI Project MU-4949-350, April.

Brown, Stephen L., 1966b, Industrial Vulnerability to Nuclear Attack--San Jose, California, Stanford Research Institute, Menlo Park, California, SRI Project MU-4949-350, October.

Brown, Stephen L. and Pamela Kruzic, 1970, Agricultural Vulnerability in the National Entity Survival Context, Stanford Research Institute, Menlo Park, California, July.

Brown, Stephen L. and Ulrich F. Pilz, 1969, U.S. Agriculture: Potential Vulnerabilities, Stanford Research Institute, Menlo Park, California, January.

Brown, Stephen L., Hong Lee and Oliver S. Yu, 1968, Postattack Food Production and Food and Water Contamination, Stanford Research Institute, Menlo Park, California, June.

Brown, Stephen L. et al., 1973, Agricultural Vulnerability to Nuclear War, Stanford Research Institute, Menlo Park, California, SRI-8674, February.

Brown, William M., 1968a, On Reorganizing After Nuclear Attack, The Rand Corporation, Santa Monica, California, P-3764, January. (Also contained in National Academy of Sciences, 1968, Proceedings of the Symposium on Postattack Recovery from Nuclear War, Held at Fort Monroe, Virginia, November 6-9, 1967, Washington, D.C., April.)

Brown, William M, 1968b, Emergency Mobilization for Postattack Reorganization, Hudson Institute, Inc., Croton-(formerly Harmon-)on-Hudson, New York, HI-874/2-RR, May 15.

Brown, William M., 1970, On the Post-Attack Viability of American Institutions, The Rand Corporation, Santa Monica, California, P-4275, January.

Brown, William M., 1971, Recovery from a Nuclear Attack (A Study Based upon a Hypothetical 1973 War Scenario), Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, October.

Brown, William M., 1975, The Nuclear Crisis of 1979, Prepared for Defense Civil Preparedness Agency, WMB 75-9.

Brown, William M. and Pauline Gutelle, 1965, Population Density in the United States Urbanized Areas, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, HI-495-RR, March 22.

Brown, William M. and Herman Kahn, Editors, 1964, Non-Military Defense Policies: A Context, Reappraisal, and Commentary, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, HI-359-RR, Two Volumes, May 15.

Brown, William M. and Doris Yokelson, 1980, Postattack Recovery Strategies, Hudson Institute, Inc., Croton-(formerly Harmon-)on-Hudson, New York, November.

Bull, Elwyn M., 1971, Antibiotics Production Capacities in the Postattack Economy, Research Analysis Corp., McLean, Virginia, RAC-CR-42, December.

Bull, Elwyn M., 1973a, The Runout Production Evaluation (ROPE) Model: Structure and Methodology, American Technical Assistance Corp., McLean, Virginia, DPG-11, June.

Bull, Elwyn M., 1973b, Postattack Capabilities of the Economy in the First Ninety Days, American Technical Assistance Corp., McLean, Virginia, DPG-12, June.

Bull, Elwyn M. and 'ebron E. Adams, 1975, Postattack Resource Management, American Technical Assistance Corp., McLean, Virginia, OAD-A-CR-108, May.

Bull, Elwyn M. and Bernard Sobin, 1970, Measurement of Critical Production Capacities for Models of the Postattack Economy Research Analysis Corp., McLean, Virginia, February.

Burchardt, F.A. and K. Martin, 1947, "Western Germany and Reconstruction", Bulletin of the Oxford Institute of Statistics, December.

Byrne, W.F. and M.C. Bell, 1971, Livestock, Fallout, and a Plan for Survival in the Event of Nuclear War, U.S. Atomic Energy Commission, December.

Cairncross, A.K., 1951, "The Economic Recovery of Western Germany", Lloyds Bank Review, October.

Cannell, Rogers and Edward Schuert, 1980, Candidate Industrial Preparedness Program, Woodward-Clyde Consultants, San Francisco, California, Report 60485-A, December.

Carr, Harry C., 1975, Area Impact Evaluation: A Planning Methodology for Assessment of the Economic Viability of Local Areas During Crisis Relocation, Checchi and Co., Washington, D.C., February.

Cavers, David F., 1953, "Legal Measures to Mitigate the Effect of Atomic Attack", Bulletin of the Atomic Scientists, Volume IX.

Cavers, David F., 1955, "Legal Planning against the Risk of Atomic War", Columbia Law Review, February.

Chenault, William W., Richard E. Engler, and Peter G. Nordlie, 1967, Social and Behavioral Factors in the Implementation of Local Survival and Recovery Activities, Human Sciences Research, Inc., McLean, Virginia, HSR-RR-67/12-Ip, August.

Chenault, William W. and Peter G. Nordlie, 1967, Consumer Behavior and Worker Participation in Recovery Activities, Human Sciences Research, Inc., McLean, Virginia, HSR-RR-67/5-Tl, February.

Chenoweth, J.M. et al., 1963, A Method for Predicting Electric Power Availability Following a Nuclear Attack, 2 Volumes, National Engineering Science Co., Pasadena, California, April.

Chipman, William K., 1961, Nonmilitary Defense for the United States, Madison, Wisconsin, The National Security Studies Group at the University of Wisconsin, May.

Clark, Donald E., 1969, Techniques for Development of Postattack Recovery Management, Stanford Research Institute, Menlo Park, California, SRI Project No. MU-6250, November.

Clark, Donald E., Carl F. Miller, and George D. Hopkins, 1966, Approach to Defining Post Attack Recovery Management Concepts and Techniques, Stanford Research Institute, Menlo Park, California, Project MU-4536, November.

Clark, Paul G., 1956, Vulnerability and Recuperation of a Regional Economy: A Study of the Impact of a Hypothetical Atomic Attack on New England, Rand Corp., Santa Monica, California, RM-1809-PR, October 12.

Cochrane, Harold C., 1975, Natural Hazards and their Distributive Effects, Institute of Behavioral Science, University of Colorado, Boulder, Colorado, NSF-RA-E-75-003.

Cochrane, Harold C., 1984, "Knowledge of Private Loss and the Efficiency of Protection," Presented at the Conference on the Economics of Natural Hazards and their Mitigation, December 14-15, 1984, University of Florida.

Cochrane, Harold C. et al., 1974, Social Science Perspectives On the Coming San Francisco Earthquake: Economic Impact, Prediction, and Reconstruction, Institute For Behavioral Sciences, University of Colorado, Boulder, Colorado, Working Paper #25.

Crain, John L., 1965, Effects of Nuclear Attacks on U.S. Air Transport Systems, Stanford Research Institute, Menlo Park, California, October.

Dacy, Douglas C. and Howard Kunreuther, 1969, The Economics of Natural Disasters: Implications for Federal Policy, Free Press, New York.

Daniel, Dan O. and Joseph E. Minor, 1975, Prototype Plans for Production and Maintenance of Electric Power in Crisis Relocation, Defense Electric Power Administration, U.S. Department of the Interior, August.

Decision Science Applications, 1983, The DYNEVAL (Dynamic Economic Values) Model, Arlington, Virginia, DSA Report 475, January.

Dixon, Harvey L., D.G. Haney, and Paul S. Jones, 1960, A System Analysis of the Effects of Nuclear Attack on Railroad Transportation in the Continental United States, Stanford Research Institute, Menlo Park, California, April.

Dixon, Harvey L. and Thomas H. Tebben, 1967, Effects of Nuclear Attack on Freight Transportation Systems: Interactions and Comparisons among Modes, Stanford Research Institute, Menlo Park, California, SRI Project MU-4949-150, March.

Dolins, Lynn P., 1970, The IDA Civil Defense Economic Model: An Interim Summary, Institute for Defense Analyses, Arlington, Virginia, Note N-713(R), March.

Doll, John P., Nancy S. Borgeson, and Leland H. Towle, 1966, Methods for Evaluating the Effects of Nuclear Attack on the Ability of Power Systems to Meet Estimated Postattack Demands, Stanford Research Institute, Menlo Park California, SRI Project Nos. 4536-420 and 4949-140, September.

Douty, Christopher M., 1977, The Economics of Localized Disasters: The 1906 San Francisco Catastrophe, Arno Press, New York.

Dresch, Francis W., 1962, Review of Research on Supply Requirements Problem, Stanford Research Institute, Menlo Park California, February.

Dresch, Francis W., 1964, Resource Management for Economic Recovery Following Thermonuclear Attack, Part I: A System for Synthesis and Feedback of Essential Information, Stanford Research Institute, Menlo Park California, SRI Project No. IMU-3711, June.

Dresch, Francis W., 1965, Resource Management for Economic Recovery Following Thermonuclear Attack, Part II: Effective Control of Resources in Recovery Management, Stanford Research Institute, Menlo Park California, SRI Project No. IMU-3711, January.

Dresch, Francis W., 1968a, "Postattack Organizational Problems and Societal Vulnerability," In National Academy of Sciences, 1968, Proceedings of the Symposium on Postattack Recovery from Nuclear War, Held at Fort Monroe, Virginia, November 6-9, 1967, Washington, D.C., April.

Dresch, Francis W., 1968b, Information Needs for Post-Attack Recovery Management, Stanford Research Institute, Menlo Park California, SRI Project MU-6294, April.

Dresch, Francis W., 1969a, Methodology for the Analysis of the Vulnerability of Economic Institutions, Stanford Research Institute, Menlo Park California, SRI Project MU-6300-410, April.

Dresch, Francis W., 1969b, Requirements for Comparative Evaluation of Countermeasures to Possible Postattack Fiscal Problems, Stanford Research Institute, Menlo Park California, SRI Project 6250-054, April.

Dresch, Francis W. and Hazel B. Ellis, 1966, Methodology for Assessing Total Vulnerability, Stanford Research Institute, Menlo Park California, SRI Project MU-4949-520, August.

Dresch, Francis W. and Hazel B. Ellis, 1968, Institutional Factors in Total Vulnerability, Stanford Research Institute, Menlo Park California, SRI Project MU-4949-520, April.

Dresch, Francis W. and Hazel B. Ellis, 1974, Criteria for Early Postattack Economic Viability of Local Areas, Stanford Research Institute, Menlo Park California, SRI-2778, June.

Dresch, Francis W. and Baum S., 1973, Analysis of the U.S. and USSR Potential for Economic Recovery Following a Nuclear Attack Stanford Research Institute, Menlo Park California, SSC-TN-8974-85, January.

Dresch, Francis W. et al., 1976, Development of Prototype Crisis Relocation Plans and Planning Guidance, Stanford Research Institute, Menlo Park California, SRI-EGU-3479, May.

Earle, M. Mark et al., 1980, Multijurisdictional Responses to Urban and Regional Disasters, SRI International, Menlo Park, California, SRI International Project HSU-8838, October.

Ellson, Richard W., Jerome M. Milliman, and R. Blaine Roberts, 1984, "Measuring the Regional Economic Effects of Earthquakes and Earthquake Predictions," Journal of Regional Science.

Engineering-Science, Inc., 1963, The Recovery and Restoration of Metropolitan Water Works Following Nuclear War Attack, Arcadia, California, May.

Enke, Stephen, 1958, "Controlling Consumers in the Event of Future Wars," Quarterly Journal of Economics, November.

Eriksen, Nell J., 1975, Scenario Methodology in Natural Hazards Research, Institute of Behavioral Science, University of Colorado, Boulder, Colorado, NSF-RA-E-75-010.

Euken, 1948, "On the Theory of the Centrally Administered Economy: An Analysis of the German Experiment," Economica, February.

Faucett, Jack G., 1976a, Transportation Models for Civil Preparedness Planning, Jack Faucett Associates, Inc., Chevy Chase, Maryland, February.

Faucett, Jack G., 1976b, Interregional Transportation Analysis and Civil Preparedness Planning, Jack Faucett Associates, Inc., Chevy Chase, Maryland, November.

Feinberg, Abe , 1978, Civil Preparedness and Post-Attack U.S. Economic Recovery: A State-of-the-Art Assessment and Select Annotated Bibliography, Analytical Assessments Corp., Marina del Rey, California, AAC-TR-9204/79, October.

Fernald, Olaf et al., 1963a, Critical Industry Repair Analysis: Electric Power, Advance Research, Inc., Cleveland Ohio, April.

Fernald, Olaf et al., 1963b, Critical Industry Repair Analysis: Steel Industry, Advance Research Inc., Cleveland, Ohio, .

Fernald, Olaf et al., Advance Research, Inc., 1965a, Critical Industry Repair Analysis: Food Industry, Advance Research Inc., Needham Heights, Massachusetts, CIRA-3, April.

Fernald, Olaf et al., Advance Research, Inc., 1965b, Critical Industry Repair Analysis: Petroleum Industry, Advance Research Inc., Wellesley Hills, Massachusetts, Report CIRA-4, October.

Foget, Carl R., William H. Van Horn, and Milton Staackman, 1968, Damage to the Basic Chemical Industry from Nuclear Attack and Resulting Requirements for Repair and Reclamation, URS Systems Corp., Burlingame, California, URS-687-4, June.

Foget, Carl R. and William H. Van Horn, 1969, Availability and Use of Emergency Power Sources in the Early Postattack Period, URS Research Co., Burlingame, California, August.

Foster, Richard B. and Francis P. Hoeber, 1980, Survival, Reconstitution, and Recovery: U.S.-Soviet Assymmetries and U.S. Policy Options, SRI International, Arlington, Virginia, SRI Project 7933, February.

Friedman, Don G., 1973, "Analysis for Earthquake Insurance," In Earthquakes and Insurance, Center for Research on the Prevention of Natural Disasters, Pasadena, California: California Institute of Technology.

Friesema, H. Paul et al., 1979, Aftermath: Communities After Natural Disasters, Sage Publications, Beverly Hills, California.

Fritz, Charles E., 1961, "Disaster," In Robert K. Merton and Robert A. Nisbet, Editors, Contemporary Social Problems, Harcourt, Brace, and World, New York.

Fromm, Gary and Charles H. Movit, 1980, Development of Analytical Systems for Evaluation of U.S. Reconstitution and Recovery Programs, SRI International, Arlington, Virginia, SRI Project 7932, Technical Note CEPR-TN-7932-1, September.

Galbraith, John K., 1975, Money, Whence it Came, Where it Went, Houghton-Mifflin Co., Boston, Massachusetts.

Garland, C.D., 1972, Economic Alternatives and Policy Implications of a Strategic Commodity Reserve for National Security Considerations, PhD Thesis, Oak Ridge National Laboratory, Oak Ridge, Tennessee, March.

Gastil, Raymond D., 1964, Postattack Scenarios, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, HI-316-RR, January 15.

Gastil, Raymond D. and William Schneider, 1969, Scenario for Post-Attack Social Reorganization, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, HI-1188-RR, August 20.

Goen, Richard L., 1969, Location of Critical Industries, Stanford Research Institute, Menlo Park, California, Technical Note SSC-TN 5205-118, October.

Goen, Richard L., 1971, The Magnitude of Initial Postattack Recovery Activities, Stanford Research Institute, Menlo Park, California, SRI 7979-007, December.

Goen, Richard L. et al., 1967, Analysis of National Entity Survival, Stanford Research Institute, Menlo Park, California, SRI Project No. MU-6250-050, November.

Goen, Richard L. et al., 1969, Critical Factors Affecting National Survival, Stanford Research Institute, Menlo Park, California, SRI Project MU-6250-050, March.

Goen, Richard L., R.B. Bothun, and Frank E. Walker, 1970, Potential Vulnerabilities Affecting National Survival, Stanford Research Institute, Menlo Park, California, SRI Project EGU-7979, September.

Goen, Richard L. and William L. White, 1974, Postattack Contingency Plans for Undamaged Areas, Stanford Research Institute, Menlo Park, California, July.

Goodrich, David W. et al., 1967, Vulnerability of the Water, Sewerage and Drainage Systems in San Jose, California, Stanford Research Institute, Menlo Park, California, SRI Project MU-4949-390, October.

Greene, Mark R., 1964, "The Effect of Insurance Settlements in a Disaster," 31 The Journal of Risk and Insurance.

Greene, Jack C., Robert W. Stokley, and John K. Christian, 1979, Recovery From Nuclear Attack and Research and Action Programs to Enhance Recovery Prospects, International Center for Emergency Preparedness, Washington, D.C., December.

Grigsby, J. William, Robert P. Manly, William C. Boesman, and Janet M. Johnson, 1968, Vulnerability of the Local Petroleum Distribution System: Albuquerque, New Mexico, Checchi and Co., Washington, D.C., June.

Grimm, Bruce T., 1969, Estimation of CES Production Functions for U.S. Manufacturing by Input-Output Sector, Institute for Defense Analyses, Arlington, Virginia, P-525, July.

Haaland, Carsten M., 1977, "Availability and Shipment of Grain for Survival of a Nuclear Attack," American Journal of Agricultural Economics, May.

Haas, J. Eugene, Robert W. Kates, and Martyn J. Bowden, Editors, 1977, Reconstruction Following Disaster, The MIT Press, Cambridge, Massachusetts.

Hall, Philip S. and Patrick W. Landreth, 1975, "Assessing Some Long Term Consequences of a Natural Disaster", 1 Mass Emergencies.

Hall, Richard W., 1967, Vulnerability of Local Transportation Systems: Albuquerque, New Mexico, Stanford Research Institute, Menlo Park, California, SRI Project MU-6300-401, July.

Hall, Richard W., 1968, Effects of Nuclear Attack on Local Transportation--San Jose, California, Stanford Research Institute, Menlo Park, California, SRI Project MU-6300-401, June.

Hamberg, William A., 1969, Transportation Vulnerability Research: Review and Appraisal, 1959-1969, Stanford Research Institute, Menlo Park, California, SRI Project 6300-390, January.

Hamberg, William A., 1971, Vulnerability of a Zonal Transportation System, Stanford Research Institute, Menlo Park, California, SRI Project MSU-8590, August.

Hamberg, William A. and Richard W. Hall, 1970, Vulnerability and Surviving Capability of the Nation's Transportation Systems: Development and Test of Methodology, Stanford Research Institute, Menlo Park, California, SRI Project 7862, March.

Hanunian, Norman, 1966, Dimensions of Survival: Postattack Survival Disparities and National Viability, Rand Corp., Santa Monica, California, RM-5140-TAB, November.

Harbridge House, Inc., An Inquiry into the Long-Term Economic Impact of Natural Disasters in the United States, Harbridge House, Inc., Boston Massachusetts.

Harker, R.A., 1966, Attack Preparation Scenario: Five City Study, Stanford Research Institute, February.

Heller, Walter, 1949, "Tax and Monetary Reform in Occupied Germany", National Tax Journal.

Hill, Gary and Peter C. Gardiner, 1979, Managing the U.S. Economy in a Postattack Environment: A System Dynamics Model of Viability, Analytical Assessments Corp, Marina del Rey, California, AAC-TR-9205/79, November.

Hirshleifer, Jack, 1953, War Damage Insurance, The Rand Corporation, Santa Monica, California, P-519, May. (A version of this paper also appears in Review of Economics and Statistics, 1953, pp. 144-153).

Hirshleifer, Jack, 1954, Compensation for War Damage: An Economic View, The Rand Corporation, Santa Monica, California, P-517, April 29.

Hirshleifer, Jack, 1955, Some Thoughts on the Social Structure After a Bombing Disaster, The Rand Corporation, Santa Monica, California, P-674, August 18.

Hirshleifer, Jack, 1963, Disaster and Recovery: A Historical Survey, The Rand Corporation, Santa Monica, California, RM-3079-PR, April.

Hirshleifer, Jack, 1965, Economic Recovery, The Rand Corporation, Santa Monica, California, P-3160, August.

Hirshleifer, Jack, 1966, Disaster and Recovery: The Black Death in Western Europe, The Rand Corporation, Santa Monica, California, RM-4700-TAB, February.

Hudson Institute, 1964, Source Book on Non-Military Defense, 6 volumes, Croton-(formerly Harmon-)on-Hudson, New York, HI-417-RR.

Ikle, Fred C., 1958, The Social Impact of Bomb Destruction, University of Oklahoma Press, Norman, Oklahoma.

Ingham, Barbara and Colin Simmons, 1981, "The Two World Wars and Economic Development," World Development, August.

Jackson, Terence G., 1967, German Wartime Industrial Controls: An Analogy to Recovery from Nuclear Attack, Stanford Research Institute, Menlo Park, California, SRI Project 4949-351, October.

Jackson, Terence G., 1969, Postwar Monetary Reform in Severely Damaged Economy: Its Role in Recovery from Nuclear Attack, Stanford Research Institute, Menlo Park, California, SRI Project MU-6300-460, April.

Jones, Paul S., 1961, The Effects of Nuclear Attack on Rail Activity Centers, Stanford Research Institute, Menlo Park, California, SRI Project IMU-3084, July.

Kahn, Herman et al., 1958, Report on a Study of Non-Military Defense, The Rand Corp., Santa Monica, California, R-322-RC, July 1.

Karlik, John, 1967, Possibilities for Postattack Foreign Assistance to the United States, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, HI-868-D, July 18.

Karlik, John, 1968, Aspects of Postattack Economic Recovery, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, HI-872-RR, May 15.

Karlson, June, 1968, A Context Study of Postattack Research, Volume IV: Research Review, The Mitre Corp., Bedford, Massachusetts, M68-17, February.

Karlson, June, Ellen Langer, and Frederick J. Wells, 1969a, Postattack Research, Volume V: Reviews and Abstracts of Research on Surviving Economic Production Potential, The Mitre Corp., Bedford, Massachusetts, M68-22, February.

Karlson, June, Ellen Langer, and Frederick J. Wells, 1969b, Postattack Research, Volume VI: Reviews and Abstracts of Research on Critical Postattack Resources and Industries, The Mitre Corp., Bedford, Massachusetts, M68-22, August.

Katz, Arthur M., 1982, Life After Nuclear War: The Economic and Social Impacts of Nuclear Attacks on the United States, Ballinger Publishing Co., Cambridge, Massachusetts.

Kennedy, Michael and Kevin N. Lewis, 1981, On "Keeping Them Down" Or Why Do Recovery Models Recover So Fast?, Rand Corporation, Santa Monica, California, P-6531, June.

Kerr, James W., Robert A. Harker, and Frederick C. Rockett, 1967, Scenarios in Civil Preparedness Research: A Five City Study Analytical Report, Defense Civil Preparedness Agency, January.

Kiker, B.F. and James L. Cochrane, 1973, "War and Human Capital in Western Economic Analysis," History of Political Economy, Fall.

King, Robert B., Anna M. Kleiner, and William O. Hambacher, 1965, Higher Education and the Postattack Period, HRB-Singer, Inc., State College, Pennsylvania, 79511-F, August.

King, Robert B. and Anna M. Kleiner, 1967, Social Institutions and Thermonuclear War--A Case Study of Higher Education, HRB-Singer, Inc., State College, Pennsylvania, 94611-F, January.

Klopstock, Fred H., 1946, "Monetary Reform in Liberated Europe," American Economic Review.

Krutilla, John V., 1966, "An Economic Approach to Coping with Flood Damage", Water Resources Research.

Kunreuther, Howard, 1967, "The Peculiar Economics of Disasters," Papers in Non-Market Decision Making, III, Fall.

Kunreuther, Howard, 1968, "The Case for Comprehensive Disaster Insurance," Journal of Law and Economics.

Kunreuther, Howard, 1973, Recovery From Natural Disasters: Insurance or Federal Aid, American Enterprise Institute, Washington, D.C., December.

Kunreuther, Howard, 1976, "Limited Knowledge and Insurance Protection," Public Policy, Spring.

Kunreuther, Howard, 1978, Disaster Insurance Protection: Public Policy Lessons, John Wiley and Sons, New York.

Kunreuther, Howard, 1979, "The Changing Societal Consequences of Risks from Natural Hazards," Annals of the American Academy of Political and Social Science, May.

Kunreuther, Howard and Ellisandra S. Fiore, 1966, The Alaskan Earthquake: A Case Study in the Economics of Disaster, Institute for Defense Analyses, Arlington, Virginia, Study S-228, February.

Lambert, Brian K., 1976, Electric Power Systems Vulnerability Methodology, Defense Electric Power Administration, U.S. Department of Interior, August.

Lambert, Brian K. and Joseph E. Minor, 1973a, Vulnerability of Regional Electric Power Systems to Nuclear Weapons Effects, Texas Tech University, Lubbock, Texas, May.

Lambert, Brian K. and Joseph E. Minor, 1973b, Vulnerability of Regional Manufacturing and Resource Systems to Nuclear Weapons Effects, Texas Tech University, Lubbock, Texas, August.

Lambert, Brian K. and Joseph E. Minor, 1975a, Regional Manufacturing Systems: Nuclear Weapons Effects and Civil Defense Actions, Institute for Disaster Research, Lubbock, Texas, TTU-391-3119, April.

Lambert, Brian K. and Joseph E. Minor, 1975b, Vulnerability of Regional and Local Electric Power Systems: Nuclear Weapons Effects and Civil Defense Actions, Defense Electric Power Administration, U.S. Department of Interior, July.

LaRiviere, Philip D. and Hong Lee, 1966, Postattack Recovery of Damaged Urban Areas, Stanford Research Institute, Menlo Park, California, November.

Laurino, Richard K., 1967, National Entity Survival Following Nuclear Attack, Stanford Research Institute, Menlo Park, California, SRI Project No. MU-6250, Technical Note TN-OAP-28, December. (The paper also appears in National Academy of Sciences, 1968, Proceedings of the Symposium on Postattack Recovery from Nuclear War, Held at Fort Monroe, Virginia, November 6-9, 1967, Washington, D.C., April.)

Laurino, Richard K. and Francis W. Dresch, 1971, National Entity Survival: Measure and Countermeasure, Stanford Research Institute, Menlo Park, California, SRI-EGU-7979, June.

Laurino, Richard K. and Francis W. Dresch, 1980, Continuity of Government for Postattack Recovery: Economic/Industrial Aspects, Center for Planning and Research, Inc., Palo Alto, California, November.

Laurino, Richard K., Peter B. Bjorklund, and Carl F. Miller, 1973, A Graded Set of Summary Scenarios for Nuclear Attack, System Sciences, Inc., Palo Alto, California, May 31.

Laurino, Richard K., Peter B. Bjorklund, and Carl F. Miller, 1974, Nuclear War Scenarios for Simulation Exercises, Center for Planning and Research, Inc., Palo Alto, California, November 15.

Laurino, Richard K. et al., 1970, A Discussion of Multi-Element Value Systems for Urban/Industrial Areas, Stanford Research Institute, Menlo Park, California, Technical Note SSC-TN-8260-2, January 16.

Laurino, Richard K. et al., 1977, Economic and Industrial Aspects Of Crisis Relocation: An Overview, Center for Planning and Research, Inc., Palo Alto, California, May.

Laurino, Richard K. et al., 1978, Impacts of Crisis Relocation on U.S. Economic and Industrial Activity, Center for Planning and Research, Inc., Palo Alto, California, October.

Laurino, Richard K. et al., 1980, Key Economic Problems and Guidelines for Crisis Relocation, Center for Planning and Research, Inc., Palo Alto, California, June.

Leavitt, Jane, 1974, Analysis and Identification of Nationally Essential Industries: Volume I: Theoretical Approach, Institute for Defense Analyses, Arlington, Virginia, P-972, March.

Lee, Hong, 1964, Vulnerability of Municipal Water Facilities to Radioactive Contamination From Nuclear Attacks, Stanford Research Institute, Menlo Park, California, March.

Lee, Hong, 1968a, Industrial Recovery Assessment Techniques, Stanford Research Institute, Menlo Park, California, SRI Project MU-6300-350, February.

Lee, Hong, 1968b, Industrial Model Matrix: Inputs and Outputs, Stanford Research Institute, Menlo Park, California, SRI Project MU-6300-350, June.

Lee, Hong, 1968c, Industrial Recovery Model Constraints, Stanford Research Institute, Menlo Park, California, SRI Project MU-6300-350, October.

Lee, Hong, 1969, Industrial Recovery Model: Bread Production Network, Stanford Research Institute, Menlo Park, California, SRI Project MU-6300-350, March.

Lee, Hong, 1970, Industrial Recovery Modeling: Postattack Demands and Potentials, Stanford Research Institute, Menlo Park, California, SRI Project MU-6300-350, January.

Lee, Hong et al., 1968a, Industrial Production and Damage Repair Following Nuclear Attack, Stanford Research Institute, Menlo Park, California, March.

Lee, Hong et al., 1968b, Denial of Industrial Production Due to Fallout Following Nuclear Attack, Stanford Research Institute, Menlo Park, California, May.

Lerner, Harvey A., J. William Grigsby, and Janet M. Johnson, 1967, Vulnerability of the Local Petroleum Distribution System: San Jose, California, Checchi and Co., Washington, D.C., April.

Levine, Herbert S. and Mark M. Earle, 1980, An Approach to the Comparative Analysis of the U.S. and Soviet Economies, SRI International, Arlington, Virginia, SRI Project 7932, September.

Lewis, Tracy R. and David Nickerson, 1984, "Self Protection Against Natural Hazards," Presented at the Conference on the Economics of Natural Hazards and their Mitigation, December 14-15, 1984, University of Florida.

Li, Lode, Talbot Page, and Richard McKelvey, 1984, "Research Incentives and Market Structure: The Case of Insurance for a Natural Hazard," Presented at the Conference on the Economics of Natural Hazards and their Mitigation, December 14-15, 1984, University of Florida.

Lind, Robert, 1967, "Flood Control Alternatives and the Economics of Flood Protection," Water Resorces Research.

Livermore, Shaw, 1968, "Resources Management," In National Academy of Sciences, 1968, Proceedings of the Symposium on Postattack Recovery from Nuclear War, Held at Fort Monroe, Virginia, November 6-9, 1967, Washington, D.C., April.

Lokey, William M. et al., 1980, Labor Mobilization Project, Washington State Department of Emergency Services, Seattle, Washington, May 15.

Lokey, William M. et al., 1981, Labor Mobilization Project (Extended Period), Washington State Department of Emergency Services, Seattle, Washington, April 15.

Ludgin, Quentin, 1968, "Crisis Measures for Post-Attack Industrial Recovery", In William M. Brown, Emergency Mobilization for Postattack Reorganization, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, May Appendix B.

Lutz, F.A., 1949, "The German Currency Reform and the Revival of the German Economy", Economica, May.

Manly, Robert P., Harvey A. Lerner, and J. William Grigsby, 1970, Petroleum Distribution, Gross National Product, and System Vulnerability: Methods of Analysis, Checchi and Co., Washington, D.C., October.

Marr, Paul D., 1958, Food Supply and Production Following a Massive Nuclear Attack, Stanford Research Institute, Menlo Park, California, October.

Marshall, John, 1984, "Optimum Insurance for Natural Hazards for People Who Don't Want Any," Presented at the Conference on the Economics of Natural Hazards and their Mitigation, December 14-15, 1984, University of Florida.

Massell, Benton F. and Sidney G. Winter, 1961, Postattack Damage Assessment: A Conceptual Analysis, The Rand Corporation, Santa Monica, California, RM-2844-PR, November.

Massell, Benton F. and Charles Wolf, 1962, Economic Development and Post-War Recuperation: A Comparison of Industrial Priorities, The Rand Corporation, Santa Monica, California, RM-2952-PR, January. (A version of the paper also appears in the Journal of Industrial Economics, 1963).

McFadden, Fred R. and Charles D. Bigelow, 1966, Development of Rapid Shutdown Techniques for Critical Industries, Stanford Research Institute, Menlo Park, California, January.

McGill, James T. et al., 1972, Methodologies for Evaluating the Vulnerability of National Systems; Volume 1: Methodologies and Examples, Institute for Defense Analyses, Arlington, Virginia, Study S-394, June.

Mendershausen, Horst, 1949, "Prices, Money, and the Distribution of Goods in Postwar Germany", American Economic Review, June.

Miller, Carl F. and Richard K. Laurino, 1973, A Concept for Postattack Nuclear Emergency Operations, Dikewood Corp., August.

Miller, Carl F. and S. Duane Stratton, 1980, Expedient Measures in Postattack Industrial Recovery: Petroleum Refining, Center for Planning and Research, Inc., Palo Alto, California, December 1.

Minor, Joseph E., Andrew J. Pryor, and George E. Commerford, 1969, Evaluation of Industrial Systems Interrelationships and Vulnerability to Nuclear Attack, Southwest Research Institute, San Antonio, Texas, Project 03-2401, November.

Minor, Joseph E., Brian K. Lambert and John Wittman, 1972, Impact of the Lubbock Storm on Regional Systems, Texas Tech University, Lubbock, Texas, Project 391-3118, June.

Minor, Joseph E., Brian K. Lambert, and Milton L. Smith, 1972, Vulnerability of Regional Manufacturing Systems to Nuclear Weapons Effects, Texas Tech University, Lubbock, Texas, Project 391-3118, May.

Moll, Kendall D., Jack H. Cline, and Paul D. Marr, 1960, Postattack Farm Problems, Part I: The Influence of Major Inputs on Farm Production, Stanford Research Institute, Menlo Park, California, December.

Munroe, Tapan and Kenneth P. Ballard, 1983, "Modeling the Economic Disruption of a Major Earthquake in the San Francisco Bay Area: Impact on California," The Annals of Regional Science, November.

National Academy of Sciences, 1963, Project Harbor: Report of Panel on Post-Attack Recovery Program, Summer Studies Center, Little Harbor Farm, Woods Hole, Massachusetts, August.

National Academy of Sciences, 1968, Proceedings of the Symposium on Postattack Recovery from Nuclear War, Held at Fort Monroe, Virginia, November 6-9, 1967, Washington, D.C., April.

National Academy of Sciences, 1975, Earthquake Prediction and Public Policy, Washington, D.C.

National Academy of Sciences, 1978, A Program of Studies in the Socioeconomic Effects of Earthquake Predictions, Washington, D.C.

Negaro, Bertrand, 1948, "Hungary's Recent Monetary Crisis and its Theoretical Meaning", American Economic Review, September.

Nevin, Robert L., 1969a, Vulnerability of the Albuquerque Water Supply System: Five City Study, Stanford Research Institu Menlo Park, California, June.

Nevin, Robert L., 1969b, Vulnerability of the Albuquerque Sanitary Sewerage and Storm Drainage Systems, Stanford Research Institute, Menlo Park, California, June.

Nevin, Robert L., 1970, Vulnerability of the Detroit Water Supply System, Stanford Research Institute, Menlo Park, California, SRI-7862, September.

Nevin, Robert L. and Ellis E. Pickering, 1969, Water, Sewerage and Storm Drainage Staff Vulnerability: San Jose, California, Stanford Research Institute, Menlo Park, California, May.

Newcomer, Mabel, 1948, "War and Postwar Developments in the German Tax System," National Tax Journal, March.

Norton, John D., 1968a, Studies for an Economic Model for Survival and Recovery of a Single City, Volume I, Resource Availability and Data: Damage Assessment and Estimation of Repair Requirements, National Planning Association, Washington, D.C., June 1.

Norton, John D., 1968b, Studies for an Economic Model for Survival and Recovery of a Single City, Volume II, Economic Activities and Resources: Classification and Data Inventory, National Planning Association, Washington, D.C., November 1.

Norton, John D., 1969, Studies for an Economic Model for Survival and Recovery of a Single City, Volume III, Economic Models: Methods, Uses, Prospects, National Planning Association, Washington, D.C., April.

Office of Civil Defense, 1968, Proceedings of the Civil Defense Systems Evaluation Research Conference, Department of the Army, Washington, D.C., October 14-17, 1968.

Pearsall, Edward S., 1968, "Economic Interactions in the Postattack Environment", In Office of Civil Defense, 1968, Proceedings of the Civil Defense Systems Evaluation Research Conference, Department of the Army, Washington, D.C., October 14-17, 1968.

Peskin, Henry M., 1965, Protecting Industrial Resources Against Nuclear Attack, Institute for Defense Analyses, Arlington, Virginia, Study S-187, February.

Peskin, Henry M., 1968, "The Problem of Evaluating and Distributing Surviving Postattack Assets", In National Academy of Sciences, 1968, Proceedings of the Symposium on Postattack Recovery from Nuclear War, Held at Fort Monroe, Virginia, November 6-9, 1967, Washington, D.C., April.

Peterson, David W., William S. Silverman, Henry B. Weil, and Sarah Willard, 1980, Development of a Dynamic Model to Evaluate Economic Recovery Following a Nuclear Attack, Volume 1: Description and Simulations; Volume 2: Model Equations; Pugh-Roberts Associates, Cambridge, Massachusetts, November.

Peterson, David W., William S. Silverman, and Henry B. Weil, 1981, Development of a Dynamic Model to Evaluate the Effect of Natural Resource Policies on Recovery Following Nuclear Attack, Volume I: Description and Simulations, Pugh-Roberts Associates, Inc., Cambridge, Massachusetts, September.

Peterson, David W. et al., 1983, Development of a System Dynamics Model to Evaluate the Post-Attack Recovery Capability of the Soviet Union, Pugh-Roberts Associates, Inc., Cambridge, Massachusetts, May.

Pettee, James C., 1978, Unclassified Nuclear Case-Lesson Example of 1973 (UNCLEX-73), Volume II: National Survival after UNCLEX-73, General Services Administration, Federal Preparedness Agency, Washington, D.C., GSA/FPA/EGG, TR-112, November.

Petty, Geraldine et al., 1977, Economic Recovery Following Disaster: A Selected, Annotated Bibliography, Rand Corp., Santa Monica, California, December.

Pickering, Ellis E., 1969, Inter-Systems Relationships Local Vulnerability of Utilities: San Jose, Stanford Research Institute, Menlo Park, California, August.

Pryor, Andrew J., George E. Commerford, and Joseph E. Minor, 1968, Vulnerability of Industries Critical to National Survival in a Postattack Environment, Southwestern Research Institute, San Antonio, Texas, January.

Pugh, George E., 1978, Dynamic Post-Attack Economic Model: A New Analytical Approach, Decision Science Applications, Inc., Arlington, Virginia, Report #82.

Pugh, George E. et al., 1981, The DYNEVAL (Dynamic Economic Values) Model Decision-Science Applications, Inc., Arlington, Virginia, May.

Quarantelli, E.L., Editor, 1978, Disasters: Theory and Research, Sage Publications, Beverly Hills, California.

Quarantelli, E.L., 1982, Inventory of Disaster Field Studies in the Social and Behavioral Sciences: 1919-1979, The Disaster Research Center, Columbus, Ohio, May.

Quester, George H., 1979, Options for Accelerating Economic Recovery After Nuclear Attack, Analytical Assessments Corp., Marina del Rey, California, AAC-TR-9203/79, July.

Rainey, Charles T., 1972, Natural Disaster Operations Planning, Stanford Research Institute, Menlo Park, California, SRI Project 1177, March.

Rainey, Charles T. and Frederick Goshe, 1975, Development of Master Checklist for Planning Nuclear Defense Operations, Center for Planning and Research, Palo Alto, California, October.

Rettger, Michael J. and Richard N. Boisvert, 1979, "Flood Insurance or Disaster Loans: An Economic Evaluation," American Journal of Agricultural Economics, August.

Richford, Maurice A. and Wendell E. Davis, 1967, City of San Jose, California: Vulnerability of Gas Utilities to Nuclear Attack, Office of Oil and Gas, U.S. Department of the Interior, July.

Richford, Maurice A. and Wendell E. Davis, 1968, City of Albuquerque, New Mexico: Vulnerability of Gas Utilities to Nuclear Attack, Office of Oil and Gas, U.S. Department of the Interior, September.

Richford, Maurice A. and Wendell E. Davis, 1971, City of Detroit, Michigan: Vulnerability of Gas Utilities to Nuclear Attack, Office of Oil and Gas, U.S. Department of the Interior, July.

Rockett, Frederick C. and William M. Brown, 1966, Crisis Preparations For Postattack Economic Recovery, Hudson Institute, Croton-(formerly Harmon-)on-Hudson, New York, HI-661-RR, July 15.

Rogers, George W., 1970, "Impact of the Earthquake on the Economy of Alaska," In The Great Alaska Earthquake of 1964: Human Ecology, National Academy of Sciences, Washington, D.C.

Ross, Howard R., 1967, U.S. Passenger Transportation: An Inventory of Resources and an Analysis of Capabilities of Surface Modes, Stanford Research Institute, Menlo Park, California, SRI Project MU-4949-150, March.

Rubin, Claire B., 1981, Long Term Recovery From Natural Disasters: A Comparative Analysis of Six Local Experiences, Academy for Contemporary Problems, Washington, D.C., September.

Ryan, John W. et al., 1974, A Damage Assessment Model for Agricultural Crops, Stanford Research Institute, Menlo Park, California, SRI-EGU-2729, September.

Sachs, Abner and Judith A. Timmerman, 1969, Economic Structure of the United States Using the County as a Functional Base, Institute for Defense Analyses, Arlington, Virginia, P-511, April.

Sachs, Abner and J.D. Kiernan, 1972, Natural Disasters Operations Planning for Slowly Developing Disasters--Vol. 1, Institute for Defense Analyses, Arlington, Virginia, July.

Sachs, Abner and Jane Leavitt, 1974, Analysis and Identification of Nationally Essential Industries, Volume 2: Methodology and Results, Institute for Defense Analyses, Arlington, Virginia, September.

Schulze, William et al., 1984, "The Economics of Earthquake Prediction: A Benefit-Cost Analysis for the Los Angeles Area," Presented at the Conference on the Economics of Natural Hazards and their Mitigation, December 14-15, 1984, University of Florida.

Sharfman, Peter, Project Director, 1979, The Effects of Nuclear War, Office of Technology Assessment, Washington, D.C.

Shavell, Henry, 1948, "Taxation Reform in Occupied Japan," National Tax Journal.

Simpson, Arthur W. and and John W. Billheimer, 1980, Food System Support of the Relocation Strategy in California, Two Volumes, Systan, Inc., Los Altos, California, D-162, September.

Smith, V. Kerry, 1984, "Benefit Analysis for Natural Hazards," Presented at the Conference on the Economics of Natural Hazards and their Mitigation, December 14-15, 1984, University of Florida.

Snyder, Monroe B. and Alfred J. Farina, 1967, Methods and Techniques for Postattack Manpower Utilization, Human Sciences Research, Inc., McLean, Virginia, HSR-RR-67/11-Mn, August.

Sobin, Bernard, 1968a, "A Survival Model of Postattack Physical Capacities," In National Academy of Sciences, 1968, Proceedings of the Symposium on Postattack Recovery from Nuclear War, Held at Fort Monroe, Virginia, November 6-9, 1967, Washington, D.C., April.

Sobin, Bernard, 1968b, A Model of Technological Capacity to Support Survivors of Nuclear Attack: Model, Research Analysis Corp., McLean, Virginia, RAC-TP-313, September.

Sobin, Bernard, 1969, Model of Economic Capability after Nuclear Attack, Research Analysis Corp., McLean, Virginia, RAC-TP-352, April.

Sobin, Bernard, 1970, Post-Attack Recovery, Research Analysis Corp., McLean, Virginia, RAC-P-51, June.

Sorkin, Alan L., 1982, Economic Aspects of Natural Hazards, Lexington Books, Lexington, Massachusetts.

Staackman, Milton, William H. Van Horn and Carl R. Foget, 1970, Damage to the Drug Industry from Nuclear Attack and Resulting Requirements for Repair and Reclamation, URS Research Co., San Mateo, California, URS 796-4, July.

Stephens, Maynard M., 1970, Minimizing Damage to Refineries from Nuclear Attack, Natural and Other Disasters, Office of Oil and Gas, U.S. Department of the Interior, Washington, D.C., February.

Stephens, Maynard M., 1973, Vulnerability of Total Petroleum Systems, Office of Oil and Gas, U.S. Department of the Interior, Washington, D.C., May.

Stephens, Maynard M. and Joseph A. Golasinski, 1974, Vulnerability of Natural Gas Systems, Office of Oil and Gas, U.S. Department of the Interior, Washington, D.C., June.

Strell, P.F., 1968, Development and Improvements of Methodology for Strategic Analysis of Arms: Industrial Recovery Analysis (IRA NEM), Volume VII, U.S. Arms Control and Disarmament Agency, Washington, D.C., ACDA/WEC-133, May.

Sullivan, Roger J. et al., 1979, Survival During the First Year After a Nuclear Attack, System Planning Corp., Arlington, Virginia, SPC 488, December.

Swart, Phillip., 1967, Vulnerability Analysis of Electric Power Distribution Facilities: San Jose, California, Defense Electric Power Administration, U.S. Department of the Interior, Washington, D.C., November.

Swart, Phillip, 1969, Vulnerability Analysis of Electric Power Distribution Systems: Albuquerque, New Mexico, Defense Electric Power Administration, U.S. Department of the Interior, Washington, D.C., June.

Swart, Phillip, 1970, Vulnerability Analysis of Electric Power Distribution Systems: Detroit, Michigan, Defense Electric Power Administration, U.S. Department of the Interior, Washington, D.C., November.

Tate, James H. and John W. Billheimer, 1967, Development of Rapid Shutdown Techniques for Critical Industries: The Aluminum Industry, Stanford Research Institute, Menlo Park, California, September.

Thayer, Sanford B. and Willis W. Shaner, 1960, The Effects of Nuclear Attacks on the Petroleum Industry, Stanford Research Institute, Menlo Park, California, SRI Project IU-3084, July.

Truppner, William C., 1965, Nuclear Blast Effects on a Metropolitan Economy, Institute for Defense Analyses, Arlington, Virginia, Study S-209, September.

Truppner, William C., 1967, County Reference Data for Civil Defense Applications, Institute for Defense Analyses, Arlington, Virginia, Study S-300, April.

Turek, Joan L., 1969, "Repressed Inflation and its Effect on the German Economy during World War II and the Early Occupation Period," In Bernard Sobin, 1969, Models of Economic Capability after Nuclear Attack, Appendix B, Research Analysis Corp., April.

Turrentine, Donald, 1968a, A Context Study of Postattack Research, Volume I: Summary, The Mitre Corp., Bedford, Massachusetts, M68-17, February.

Turrentine, Donald, 1968b, A Context Study of Postattack Research, Volume II: Approach, The Mitre Corp., Bedford, Massachusetts, M68-17, February.

Turrentine, Donald, 1968c, A Context Study of Postattack Research, Volume III: Model Development, The Mitre Corp., Bedford, Massachusetts, M68-17, February.

U.S. Congress, Joint Committee on Defense Production, 1976, Defense Industrial Base: Industrial Preparedness and Nuclear War Survival, Hearings before the Joint Committee on Defense Production, 94th Cong., 2nd Sess., November 17.

U.S. Department of Agriculture, 1964, Food Supplies Available by Counties in Case of a National Emergency, Economic Research Service, Agricultural Report #57, July.

U.S. Department of Agriculture, 1977, Analysis of U.S. Food Industry in a National Emergency, Food Programs Branch, Emergency Preparedness Division, Washington, D.C., July.

U.S. General Accounting Office, 1979, Key Crude Oil and Products Pipelines are Vulnerable to Disruptions, Washington, D.C., EMD-79-63, August 27.

Van Horn, William H., 1972, The Construction Industry: Vulnerability to Nuclear Attack and Postattack Capabilities, URS Research Co., San Mateo, California, URS 7037-5, August.

Van Horn, William H, Gail B. Boyd, and Carl R. Foget, 1967, Repair and Reclamation of Gas and Electric Utility Systems, URS Corp., Burlingame, California, URS 669-6, July.

Van Horn, William H. and O. Leon Crain, 1975, Process Control Instrumentation: Vulnerability and Manufacturer/User Response to Nuclear Attack, URS Research Co., San Mateo, California, URS 7326-6, February.

Vestermark, S.D., Editor, 1966, Vulnerabilities of Social Structure: Studies of the Social Dimension of Nuclear Attack, Human Sciences Research, Inc., McLean, Virginia, December.

Vinso, Joseph D., [illegible]77, Financial Implications of Natural Disasters: Some Prelimin[illegible] [illegible]ications, University of Pennsylvania, Department of Decision Science[illegible], [illegible]adelphia, Pennsylvania, Working Paper 77-01-10, January.

Walker, Frank E., 1969, Estimating Production and Repair Effort in Blast-Damaged Petroleum Refineries, Stanford Research Institute, Menlo Park, California, SRI Project MU-6300-620, July.

Wetzler, Elliott, 1970, The Structure of the IDA Civil Defense Economic Model, Institute for Defense Analyses, Arlington, Virginia, Paper P-674, August.

Wheeler, Jimmy, 1980, "The International Sector in Nuclear Crisis," In William M. Brown and Doris Yokelson, 1980, Postattack Recovery Strategies, Appendix A, Hudson Institute, Croton-on-Hudson, New York, November.

White, Gilbert, Editor, 1974, Natural Hazards: Local, National, Global, Oxford University Press, New York.

White, Gilbert, 1975, Flood Hazard in the United States: A Research Assessment, Institute of Behavioral Science, University of Colorado, Boulder, Colorado.

White, Gilbert and J. Eugene Haas, 1975, Assessment of Research on Natural Hazards, The MIT Press, Cambridge, Massachusetts.

Williamson, Oliver E. and Kendall D. Moll, 1961, Postattack Farm Problems, Part II: Attack Effects on Inputs and Farm Output, Stanford Research Institute, Menlo Park, California, October.

Winter, Sidney G., 1961, Economic Recovery From The Effects of Thermonuclear War, The Rand Corp., Santa Monica, California, P-2416, August 22.

Winter, Sidney G., 1963, Economic Viability After Thermonuclear War: The Limits of Feasible Production, The Rand Corporation, Santa Monica, California, RM-3436-PR, September.

Winter, Sidney G., 1966, "Societal Recovery after Nuclear War: The Economic Dimensions," In Vestermark, S.D., Editor, 1966, Vulnerabilities of Social Structure: Studies of the Social Dimension of Nuclear Attack, Human Sciences Research, Inc., McLean, Virginia, December.

Winter, Sidney G., 1968, "The Federal Role in Postattack Economic Organization," In National Academy of Sciences, 1968, Proceedings of the Symposium on Postattack Recovery from Nuclear War, Held at Fort Monroe, Virginia, November 6-9, 1967, Washington, D.C., April. (The paper also appears in Rand Corporation, Santa Monica, California, P-3737, November).

Wood, Marshall K., 1965, "PARM--An Economic Programming Model," Management Science, May.

Wright, J. and B. Smith, 1965, Measures of Effectiveness of Attack, Engineering Strategic Studies Group, Office of Chief Engineer, Department of the Army, June.

Wright, James D. et al., 1979, After the Cleanup: Long Range Effects of Natural Disasters, Sage Publications, Beverly Hills, California. (A version of this paper also appears in Peter H. Rossi et al., 1978, "Are There any Long Term Effects of American Natural Disasters", Mass Emergencies, September).

Wright, James D. and Peter H. Rossi, 1981, Social Science and Natural Hazards, Abt Books, Cambridge, Massachusetts.

Yorke, E.N. et al., 1978, Industrial Plant Hardness, Phase II Boeing Aerospace Co., Seattle, Washington, April.

INTERNAL DISTRIBUTION

1. M. V. Adler
2. D. J. Bjornstad
3. B. L. Bush
4. R. A. Cantor
5. C. Chester
6. L. M. Cochran
7. T. R. Curlee
8. R. M. Davis
9. R. J. Friar
10. W. Fulkerson
11. I. G. Harrison
12. K. G. Gant
13-28. L. J. Hill
29. E. L. Hillsman
30. D. W. Jones
31. C. R. Kerley
32. R. Lee
33. F. C. Maienschein
33. L. N. McCold
34. S. McConathy
35. D. M. Neal
36. R. B. Shelton
37. J. H. Sorenson
38. F. Southworth
39. G. G. Stevenson
40. P. J. Sullivan
41. D. P. Vogt
42. T. J. Wilbanks
43. Central Research Library
44. Document Reference Section
45-46. Laboratory Records Department
47. Laboratory Records (RC)
48. ORNL Patent Office

EXTERNAL DISTRIBUTION

49. The American Civil Defense Association (TACDA), P.O. Box 1057, Starke, FL 32091.

50. American National Red Cross, Attn: Annie Bartholomew, Disaster Operations, 17th & D Street, N.W., Washington, DC 20006.

51. Dr. William Anderson, Division of Fundamental Research for Emerging and Critical Engineering Systems, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550.

52. Dr. Earl J. Baker, President, Hazards Management Group, 1342 Jackson Street, Tallahassee, FL 32303.

53. Dr. Bela Banathy, Far West Laboratory, 1855 Folsom Street, San Francisco, CA 94103.

54. Mr. Robert J. Baskin, Yankelovich, Skelly and White, Inc., 969 High Ridge Road, Stamford, CT 06905.

55. Mr. H. Earle Belue, Health Resources and Services Administration, DHHA/PHS, Room 17A-55 Parklawn Building, 5600 Fishers Lane, Rockville, MD 20857.

56. Mr. John Billheimer, SYSTAN, Inc., P.O. Box U, 343 Second Street, Los Altos, CA 94022.

57. Mr. Milton L. Brooks, Emergency Coordinator, Urban Mass Transit Administration, DOT, 400 Seventh Street, S.W., Washington, DC 20590.

58. Reginald Brown, Center for Strategic and International Studies, Georgetown University, 1800 K Street, N.W., Suite 400, Washington, DC 20006.

59. Bundesministerium des Innern, Graurheindorfer Strasse 198, 5300 Bonn 1, FEDERAL REPUBLIC OF GERMANY.

60-63. Canadian Defence Research Staff, ATTN: Mr. J. Ray Brown, 2450 Massachusetts Avenue, N.W., Washington, DC 20008.

64. Dr. Theodore Caplow, United Research Services, P.O. Box 20, Charlottesville, VA 22902-0020.

65. Dr. Jaime G. Carbonell, Associate Professor of Computer Science, Carnegie-Mellon University, Pittsburgh, PA 15213.

66. Mr. Robert L. Chartrand, Senior Specialist in Information Policy and Technology, Congressional Research Service, Library of Congress, Washington, DC 20540.

67. Dr. William W. Chenault, HSR, 7710 Old Springhouse Road, McLean, VA 22102.

68. Chief of Naval Research, Washington, DC 20201.

69. Dr. John Christiansen, Department of Sociology, 834 SWKT, Brigham Young University, Provo, UT 84602.

70. Director, Civilforsvarsstyrelsen, Stockholmsgade 27, 2100 Copenhagen 0, DENMARK.

71. Prof. Dr. Lars Clausen, Soziologisches Seminar der Christian-Albrechts-Universitat, Olshausenstrasse 40/60, D-2300 Kiel, FEDERAL REPUBLIC OF GERMANY.

72. Mr. Steve Coffman, Operations Center, Department of State, Washington, DC 20520.

73. Mr. Gerald W. Collins, Exec. V.P., National Defense Transportation Assn., 1612 K Street, N.W., Suite 706, Washington, D.C. 20006.

74. Ms. Barbara Conaway, Emergency Coordinator, Office of Human Development Services/DHHS, 200 Independence Avenue, S.W., Washington, DC 20201.

75. Construction Sciences Research Foundation, ATTN: Porter Driscoll, Research Coordinator, 1150 17th Street, N.W., Washington, DC 20036.

76. The Council of State Governments, Disaster Assistance Project, 1225 Connecticut Avenue, N.W., Suite 300, Washington, DC 20036.

77. Dr. Vincent Covello, Behavioral and Biological Sciences, National Science Foundation, 1800 G Street, N.W., Washington, DC 20550.

78. Director, Defense Nuclear Agency, ATTN: Bron Cikotas, Washington, DC 20305.

79-90. Defense Technical Information Center, Cameron Station, Alexandria, VA 22314.

91. Command and Control Technical Center, Department of Defense, The Pentagon, Washington, DC 20301.

92. Deputy Assistant Secretary for Energy Emergencies, Department of Energy, Forrestal Building, 1000 Independence Avenue, S.W., Washington, DC 20585.

93. Director, Office of Energy Emergency Operations, Department of Energy, Forrestal Building, 1000 Independence Avenue, S.W., Washington, DC 20585.

94. Director, Department of Military Application, Department of Energy, Washington, DC 20545.

95. Office of Assistant Manager for Energy Research and Development, Oak Ridge Operations, P.O. Box E, U.S. Department of Energy, Oak Ridge, TN 37831.

96. Mr. Danal H. Dennison, Emergency Coordinator, Office of the Secretary, Department of Treasury, 1331 G Street, N.W., Washington, DC 20220.

97. Director, Office of Emergency Transportation, Department of Transportation, 400 Seventh Street, S.W., Washington, DC 20590.

98. Mr. Robert B. Doherty, Emergency Coordinator, DHHS, 3B 10 Hubert Humphrey Building, 200 Independence Avenue, S.W., Washington, DC 20201.

99. Professor Thomas Drabek, Chairman, Department of Sociology, Denver University, Denver, CO 80208.

100. Mr. Marvin Drake, Science Applications, Inc., 1200 Prospect Street, La Jolla, CA 92037.

101. Mr. Donald Drzewiecki, Calspan Corporation, PO Box 400, Buffalo, NY 14225.

102. The Dikewood Corporation, 1613 University Blvd., N.E., Albuquerque, NM 87101.

103. Mr. Stephen J. Entin, Deputy Assistant Secretary, Office of Economic Policy, Department of the Treasury, 15th and Pennsylvania Avenue, N.W., Washington, DC 20220.

104. National Emergency Training Center, Federal Emergency Management Agency, ATTN: Learning Resource Center, Washington, DC 20472.

105-106. Federal Emergency Management Agency, ATTN: Librarian, Federal Center Plaza, 500 C Street, SW, Washington, DC 20472.

107-157. Federal Emergency Management Agency, ATTN: Dr. Ralph B. Swisher (NPCP), Federal Center Plaza, 500 C Street, SW, Room 624, Washington, DC 20472.

158. Mr. Bernard A. Gattozzi, Chief, Emergency Programs Staff, Justice Management Division, Department of Justice, 10th & Constitution Avenue, N.W., Washington, DC 20530.

159. Mr. Gordon R. Giersch, Emergency Coordinator, Federal Energy Regulatory Commission, Department of Energy, 825 No. Capitol Street, N.E., Washington, DC 20426.

160. Dr. S. Malcolm Gillis, Dean, Graduate School, Duke University, 4875 Duke Station, Durham, NC 27706.

161. Mr. Colin Green, Middlesex Polytechnic, Queensway, Enfield EN3 4SF, ENGLAND.

162. Mr. Ivars Gutmanis, President, Sterling-Hobe Corp., 1747 Pennsylvania Avenue, N.W., Suite 704, Washington, DC 20006.

163. Mr. Michael Hartley, CDR USACE [DAEN-CWO-W], Washington, DC 20314-100.

164. The Head of Sivilforsvaret, Sandakerveien 12, Postboks 8136, Oslo dep, Oslo 1, NORWAY.

165. Mr. Edward L. Hill, Director, Operations Analysis Division, Research Triangle Institute, Research Triangle Park, NC 27709.

166. Dr. Dennis Holliday, R&D Associates, PO Box 9695, Marina del Rey, CA 90291.

167. Home Office, Scientific Advisory Branch, Horseferry House, Dean Ryle Street, London SWIP 2AW, ENGLAND.

168. Hudson Institute, 620 Union Drive, Indianapolis, Indiana 46206.

169. Human Sciences Research, Inc., Westgate Research Park, 7710 Old Springhouse Road, McLean, VA 22101.

170. IIT Research Institute, 10 West 35th Street, Chicago, IL 60616.

171. Institute for Defense Analyses, Program Analysis Division, ATTN: Leo A. Schmidt, 1801 N. Beauregard Street, Alexandria, VA 22311.

172. Professor Brandon Johnson, STS Program, Michigan Technological University, Houghton, MI 49931.

173. Mr. Nolan Jones, Ph.D., National Governors Association, 444 North Capitol Street, Washington, DC 20001.

174. Mr. Ed L. Jordan, Director, Division of Emergency Preparedness Engineering Response, Nuclear Regulatory Commission, Washington, DC 20555.

175. Mr. Ralph H. Jussel, Civil Defense Coordinator, U.S. Postal Service, 475 L'Enfant Plaza West, S.W., Washington, DC 20260-2185.

176. Dr. Fritz R. Kalhammer, Vice President, Electric Power Research Institute, Post Office Box 10412, Palo Alto, CA 94303.

177. Professor Jack Kartez, Environmental Research Center, Washington State University, Pullman, WA 99164.

178. Dr. Roger Kasperson, Professor of Government and Geography, Clark University, Worcester, MA 01610.

179. Dr. Gerald Klonglan, Dept. of Sociology and Anthropology, Iowa State University, Ames, IA 50010.

180. Professor Gary Kreps, Chairman, Department of Sociology, College of William and Mary, Williamsburg, VA 23185.

181. Mr. Victor Kugajevsky, Ph.D., Executive Resource Associates, Inc., Suite 612, Crystal Square 4, 1745 Jefferson Davis Highway, Arlington, VA 22202.

182. Mr. Bernard Kulik, Deputy Associate Administrator for Disaster Assistance, Small Business Administration, 1441 L Street, N.W., Washington, DC 20416.

183. Mr. Richard K. Laurino, President, Center for Planning and Research, 2483 East Bayshore Road, Palo Alto, CA 94303.

184. Mr. Alex R. Lawrence, Emergency Coordinator, National Highway Traffic Safety Administration, 400 Seventh Street, S.W., Washington, DC 20590.

185. Professor Robert Leik, Department of Sociology, University of Minnesota, Minneapolis, MN 55455.

186. Dr. Martin Lessen, Consulting Engineer, 12 Country Club Drive, Rochester, NY 14618.

187. Mr. Michael Lindell, Battelle Human Affairs Research Centers, 4000 N.E. 41st Street, P.O. Box C-5395, Seattle, WA 98105.

188. Mr. Frank Lisella, Emergency Coordinator, Centers for Disease Control, PHS/DHHS, 1600 Clifton Road, N.E., Atlanta, GA 30333.

189. Mr. Joe Logsdon, Emergency Coordinator, Surveillance and Preparedness Division, Office of Radiation Programs, Environmental Protection Agency, 401 M. Street, S.W., Washington, DC 20460.

190. Los Alamos Scientific Laboratory, ATTN: Document Library, Los Alamos, NM 87544.

191. Dr. Mary Lystad, Chief, Center for Mental Health Studies of Emergencies, Room 6 C-12 Parklawn Building, 5600 Fishers Lane, Rockville, MD 20856.

192. Mr. Leonard Mandrgoc, USDA Emergency Coordinator, Office of Personnel, 14th and Independence Avenue, S.W., Washington, DC 20250.

193. Professor Peter May, Graduate School of Public Affairs, University of Washington, DP 30, Seattle, WA 98105.

194. Mr. George T. McCloskey, Asst. Director for Operations Support, U.S. Foreign Disaster Assistance (AID), Department of State, Washington, DC 20520.

195. Mr. William McLoughlin, Coordinator, Office of Emergency Preparedness Planning, Employment Standards Administration, Department of Labor, 200 Constitution Avenue, N.W., Washington, DC 20210.

196. Professor Dennis Mileti, Department of Sociology, Colorado State University, Ft. Collins, CO 80523.

197. Ms. Rose Mary Mims, Systems Research and Applications Corporation, 2425 Wilson Boulevard, Arlington, VA 22201.

198. Direction de la Securite Civile, Ministere de l'Interieur, 18 Rue Ernest Cognac, 92 Levallois, Paris, FRANCE.

199. Secretaire d'Administration, Ministere de l'Interieur, Direction Generale de la Protection Civile, rue de Louvain, 1, 1000 Brussels, BELGIUM.

200. Civil Defense Administration, Ministry of Interior, Ankara, TURKEY.

201. Directeur Organisatrie, Bescherming Bevoling, Ministry of Interior, Schedeldoekshaven 200, Postbus 20011, 2500 The Hague, THE NETHERLANDS.

202. Ministry of Social Services, 11 Spartis Street, Athens, GREECE.

203. Professor Joseph Minor, Institute of Disaster Research, Department of Engineering, Texas Technical University, Box 4089, Lubock, TX 79409.

204. Professor Kenneth Mitchell, Department of Geography, Rutgers University, New Brunswick, NJ 08903.

205. Mr. Terrence F. Monihan, Director, Emergency Preparedness Staff, Office of Administrative Services, Dept. of Housing & Urban Development, 451 Seventh Street, S.W., Washington, DC 20410.

206. Dr. James W. Morentz, President, Research Alternatives, 966 Hungerford Drive, Suite 31, Rockville, MD 20850.

207. National Academy of Sciences, ATTN: Library, 2101 Constitution Avenue, N.W., Washington, DC 20418.

208. Professor Jiri Nehnevajsa, Department of Sociology, 2L22 Forbes Quadrangle, University of Pittsburgh, Pittsburgh, PA 15260.

209. Professor Joanne M. Nigg, Director, Office of Hazards Studies, Wilson Hall, Room 130, Arizona State University, Tempe, AZ 85287.

210. Civil Emergency Planning Directorate, North Atlantic Treaty Organization, 1110 NATO, BELGIUM.

211. Mr. Chet Pauls, Office of Drinking Water, Environmental Protection Agency, East Tower, Room 1005, 401 M Street, N.W., Washington, DC 20460.

212. Professor Ron Perry, Center for Public Affairs, Arizona State University, Tempe, AZ 85287.

213. Mr. Laurence Pietrzak, Mission Research Corporation, PO Drawer 719, Santa Barbara, CA 93102.

214. Ms. Judy Poston, Alternate Emergency Coordinator, Office of Family Assistance, Social Security Administration, DHHS, 6401 Security Boulevard, Baltimore, MD 12135.

215. Professor Enrico Quarantelli, Director, Disaster Research Center, Department of Sociology, University of Delaware, Newark, DE 19716.

216. The RAND Corporation, ATTN: Document Library, 1700 Main Street, Santa Monica, CA 90401.

217. Professor Sridhar J. K. Rao, Department of Civil Engineering, California State University, 1250 Bellflower Boulevard, Long Beach, CA 90840.

218. Mr. Thomas P. Reutershan, Emergency Coordinator, U.S. Public Health Service, 5600 Fishers Lane, Room 4-81, Rockville, MD 20857.

219. Dr. William Riebsame, Director, Natural Hazards Research and Applications Information Center, University of Colorado, IBS #6, Box 492, Boulder, CO 80309.

220. Professor Peter Rossi, Director, Social and Demographic Research Institute, University of Massachusetts, Amherst, MA 01003.

221. Ms. Claire Rubin, Director, Natural Disaster Research Center, Program of Policy Studies in Science and Technology, George Washington University, Washington, DC 20052.

222. Dr. Abner Sachs, Science Applications, Inc., 1651 Old Meadow Road, #620, McLean, VA 22101.

223. Dr. Donald Sachs, Kaman Sciences Corp., 1911 Jefferson Davis Highway, Arlington, VA 22202.

224. Mr. Leo A. Schmidt, Institute for Defense Analyses, Program Analysis Division, 1801 N. Beauregard Street, Alexandria, VA 22311.

225. Mr. Robert F. Schneider, Disaster Coordinator, Department of Education, 400 Maryland Avenue, S.W., Washington, DC 20202.

226. Jefe, Seccion de Estudios y Planificacion, c/Evaristo San Miguel, 8 Madrid-8, ESPANA.

227. Servicio National de Proteccao Civil, Rua Bela Vista a Lapa, 57, 1200 Lisbon, PORTUGAL.

228. Almannavarnir Skirfstofa, Office of Civil Defense, Reykjavic, ICELAND.

229. Mr. Sy O. Smith, President, National Capitol Systems, Inc., 1900 L Street, N.W., Washington, DC 20036.

230. SRI International, 333 Ravenswood Avenue, Menlo Park, CA 94025.

231. Mr. Jack Stanton, Director, Emergency Response Division, Office of Emergency and Remedial Response, Environmental Protection Agency, 401 M Street, S.W., Washington, DC 20460.

232. Stato Maggiore Difesa Civile, Centro Studi Difesa Civile, Rome, ITALY.

233. Mr. Walmer E. Strope, Center for Planning and Research, 5600 Columbia Pike, Suite 101, Bailey's Crossroads, VA 22041.

234. Mr. Roger Sullivan, Ph.D., System Planning Corporation, 1500 Wilson Boulevard, Arlington, VA 22209.

235. Mr. Lloyd Swick, Principal Consultant for Public Protection, Emergency Planning Canada, Gillin Building, 141 Laurier Avenue, West, Ottawa K1A0W6, Ontario, CANADA.

236. Dr. Lorand Szalay, President, Institute for Comparative Social and Cultural Studies, 4330 East-West Highway, Suite 900, Bethesda, MD 20814.

237. Mr. M. J. Taubenslag, TASCQ Services, Inc., 3103 Jeffrey Road, Baltimore, MD 21207.

238. Technology & Management Consultants, 330 Washington Street, Suite 613, Marina del Rey, CA 90291.

239. Ms. Janet Thompson, Fire and Emergency Services Department, Home Office, Queen Anne's Gate, London, SW1H 9AT, ENGLAND.

240. Mr. Richard Torbick, Chief, Program Management Division, Federal Highway Administration, Department of Transportation 400 Seventh St., S.W., Washington, DC 20590.

241. Professor Ralph Turner, Department of Sociology, University of California, Los Angeles, CA 90024.

242. U.S. Air Force Weapons Laboratory, ATTN: Civil Engineering Division, Kirtland Air Force Base, Albuquerque, NM 87117.

243. U.S. Air Force Weapons Laboratory, ATTN: SUL Technical Library, Kirtland Air Force Base, Albuquerque, NM 87117.

244. Director, U.S. Army Ballistic Research Laboratory, ATTN: Document Library, Aberdeen Proving Ground, MD 21006.

245-246. Director, U.S. Army Ballistic Research Laboratory, ATTN: Mr. William Taylor, Aberdeen Proving Gounds, MD 21005.

247. Director, U.S. Army Engineer Waterways Experiment Station, ATTN: Document Library, PO Box 631, Vicksburg, MS 39180.

248. Director, U.S. Army Engineer Waterways Experiment Station, ATTN: Mr. W. L. Huff, PO Box 631, Vicksburg, MS 39180.

249. University Center for Social and Urban Research, Risk Analysis and Emergency Management Program, 16th Floor Cathedral of Learning, University of Pittsburgh, Pittsburgh, PA 15260.

250. URS Research Company, 155 Bovet Road, San Mateo, CA 94402.

251. Ms. Sylvia Vela, Emergency Coordinator, Office of Human Development Services, DHHS, 200 Independence Avenue, S.W., Washington, DC 20201.

252. Mr. Bryan J. Vila, Emergency Coordinator, Office of Administrative Services, Division of Enforcement and Security Management, Department of Interior, 18th and C Street, N.W., Washington, DC 20240.

253. Mr. Charles Vlek, Institute for Experimental Psychology, University of Groningen, PO Box 14, 9750 AA Haren, THE NETHERLANDS.

254. Mr. Carl Wiehle, Defense Intelligence Agency, ATTN: WDB-4C2, Washington, DC 20301.

255. Dr. Forman Williams, Department of the Aerospace and Engineering Sciences, University of California San Diego, La Jolla, CA 03027.

256. Ms. Martha Williams, Ph.D., Coordinated Science Laboratory, 1101 Springfield Avenue, University of Illinois, Urbana, IL 61801.

257. Mr. Chuck Wilton, Scientific Services, Inc., 35 Arch Street, Redwood City, CA 94062.

258. Mr. Charles Wittenberg, President, WCA, Inc., 127 State Street, Kirkland, WA 98033.

259. Civil Engineering Center/AF/PRECET, Wright Patterson Air Force Base, OH 45433.

260. Professor Sherman Wyman, Institute of Urban Studies, University of Texas, University of Texas, Arlington, TX 76019.

261. Mr. John C. Young, IEAL, 2600 Virginia Avenue, N.W., Washington, DC 20037.

262-292. Technical Information Center, U.S. Department of Energy, P.O. Box 62, Oak Ridge, TN 37831.

293-302. Energy and Economic Analysis Section External Distribution.

STUDIES OF POSTDISASTER ECONOMIC RECOVERY: ANALYSIS, SYNTHESIS, AND ASSESSMENT

Unclassified
May 1987
246 Pages

by Lawrence J. Hill
Oak Ridge National Laboratory, Oak Ridge, TN 37831-6205
Interagency Agreement: FEMA No. EMW-84-E-1737, DOE No. 40-1457-84

The purpose of this report is to analyze, synthesize, and assess the extant literature on postdisaster economic recovery in the context of providing a background for policy development. For purposes of the study, the U.S. economy was divided into two broad components--the physical infrastructure and the institutional infrastructure.

Based on an analysis of the contributions to the literature on the physical infrastructure, three conclusions were drawn. First, the magnitude of potential destruction of economic resources under hypothetical disaster scenarios has been documented. Second, problems that could potentially thwart economic recovery have been detailed. Third, the economic conditions--in a conceptual sense--under which recovery is likely to occur have been formulated.

Research on the institutional infrastructure was assessed in the context of the reconstruction of the German economy following World War II. The primary recommendation is that further analysis should be undertaken to develop an organization and stabilization program that is consistent with fiscal and monetary reform and damage compensation.

STUDIES OF POSTDISASTER ECONOMIC RECOVERY: ANALYSIS, SYNTHESIS, AND ASSESSMENT

Unclassified
May 1987
246 Pages

by Lawrence J. Hill
Oak Ridge National Laboratory, Oak Ridge, TN 37831-6205
Interagency Agreement: FEMA No. EMW-84-E-1737, DOE No. 40-1457-84

The purpose of this report is to analyze, synthesize, and assess the extant literature on postdisaster economic recovery in the context of providing a background for policy development. For purposes of the study, the U.S. economy was divided into two broad components--the physical infrastructure and the institutional infrastructure.

Based on an analysis of the contributions to the literature on the physical infrastructure, three conclusions were drawn. First, the magnitude of potential destruction of economic resources under hypothetical disaster scenarios has been documented. Second, problems that could potentially thwart economic recovery have been detailed. Third, the economic conditions--in a conceptual sense--under which recovery is likely to occur have been formulated.

Research on the institutional infrastructure was assessed in the context of the reconstruction of the German economy following World War II. The primary recommendation is that further analysis should be undertaken to develop an organization and stabilization program that is consistent with fiscal and monetary reform and damage compensation.

STUDIES OF POSTDISASTER ECONOMIC RECOVERY: ANALYSIS, SYNTHESIS, AND ASSESSMENT

Unclassified
May 1987
246 Pages

by Lawrence J. Hill
Oak Ridge National Laboratory, Oak Ridge, TN 37831-6205
Interagency Agreement: FEMA No. EMW-84-E-1737, DOE No. 40-1457-84

The purpose of this report is to analyze, synthesize, and assess the extant literature on postdisaster economic recovery in the context of providing a background for policy development. For purposes of the study, the U.S. economy was divided into two broad components--the physical infrastructure and the institutional infrastructure.

Based on an analysis of the contributions to the literature on the physical infrastructure, three conclusions were drawn. First, the magnitude of potential destruction of economic resources under hypothetical disaster scenarios has been documented. Second, problems that could potentially thwart economic recovery have been detailed. Third, the economic conditions--in a conceptual sense--under which recovery is likely to occur have been formulated.

Research on the institutional infrastructure was assessed in the context of the reconstruction of the German economy following World War II. The primary recommendation is that further analysis should be undertaken to develop an organization and stabilization program that is consistent with fiscal and monetary reform and damage compensation.

STUDIES OF POSTDISASTER ECONOMIC RECOVERY: ANALYSIS, SYNTHESIS, AND ASSESSMENT

Unclassified
May 1987
246 Pages

by Lawrence J. Hill
Oak Ridge National Laboratory, Oak Ridge, TN 37831-6205
Interagency Agreement: FEMA No. EMW-84-E-1737, DOE No. 40-1457-84

The purpose of this report is to analyze, synthesize, and assess the extant literature on postdisaster economic recovery in the context of providing a background for policy development. For purposes of the study, the U.S. economy was divided into two broad components--the physical infrastructure and the institutional infrastructure.

Based on an analysis of the contributions to the literature on the physical infrastructure, three conclusions were drawn. First, the magnitude of potential destruction of economic resources under hypothetical disaster scenarios has been documented. Second, problems that could potentially thwart economic recovery have been detailed. Third, the economic conditions--in a conceptual sense--under which recovery is likely to occur have been formulated.

Research on the institutional infrastructure was assessed in the context of the reconstruction of the German economy following World War II. The primary recommendation is that further analysis should be undertaken to develop an organization and stabilization program that is consistent with fiscal and monetary reform and damage compensation.

☆U.S. GOVERNMENT PRINTING OFFICE 1987—748-168/60041